. DOT-TSC-NHTSA-73-3, I

HS-800925

Supersedes PB-224 284/0 April 1973

ORATORY EVALUATION OF ALCOHOL SAFETY INTERLOCK SYSTEMS, VOLUME I - SUMMARY REPORT

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January 1974
FINAL REPORT

Prepared for
DEPARTMENT OF TRANSPORTATION
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
Research Institute
Washington DC 20591

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
HS-800925		

4. Title and Subtitle	5. Report Date
LABORATORY EVALUATION OF ALCOHOL SAFETY INTERLOCK SYSTEMS, ~~VOLUME I~~ - SUMMARY REPORT. v. 1	January 1974
	6. Performing Organization Code
7. Author(s) Charles N. Abernethy, III E. Donald Sussman	8. Performing Organization Report No. DOT-TSC-NHTSA-73-3, I
9. Performing Organization Name and Address Department of Transportation Transportation Systems Center Kendall Square Cambridge MA 02142	10. Work Unit No. HS306
	11. Contract or Grant No.
12. Sponsoring Agency Name and Address Department of Transportation National Highway Traffic Safety Administration Research Institute Washington DC 20591	13. Type of Report and Period Covered Final Report 8/71 - 10/72
	14. Sponsoring Agency Code

15. Supplementary Notes

Supersedes PB-224 284/0 April 1973

16. Abstract This report contains the results of an experimental and analytical evaluation of instruments and techniques designed to prevent an intoxicated driver from operating his automobile. The prototype "Alcohol Safety Interlock Systems" tested were developed both by private industry and by the Transportation Systems Center and all were drawn from a class of instruments which detect intoxication by measuring changes in the subjects ability to perform a psychomotor task. The final report consists of the following documents:

Volume I, Summary Report - Summarizes all of the ASIS evaluation work performed through July 1972 and the results of the evaluation. Volume I is supported by an extensive appendix.

Volume II, Instrument Screening Experiments - Contains details of the experiments conducted by the Guggenheim Center, Harvard School of Public Health, including experimental procedures, results and some preliminary data analyses.

Volume III, Instrument Performance at High BAL - Contains the results of the experimental work performed by Dunlap and Associates, Inc., covering the performance of subjects with relatively high blood alcohol levels on selected instruments.

17. Key Words	18. Distribution Statement
Alcohol, intoxication interlock, intoxicated performance, habitual drinker	DOCUMENT IS AVAILABLE TO THE PUBLIC THROUGH THE NATIONAL TECHNICAL INFORMATION SERVICE, SPRINGFIELD, VIRGINIA 22151.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	188	

Form DOT F 1700.7 (8-69)

PREFACE

The work described in this report was performed in support of an overall program at the Transportation Systems Center designed to develop and evaluate Alcohol Safety Interlock Systems (ASIS). This program is sponsored by the Department of Transportation through the National Highway Traffic Safety Administration's Research Institute.

This report contains the results of an experimental and analytical evaluation of instruments and techniques designed to prevent an intoxicated driver from operating his automobile. The prototype ASIS units tested were developed both by private industry and by the Transportation Systems Center; all were drawn from a class of instruments which detect intoxication by measuring changes in a subject's ability to perform a psychomotor task. The report consists of the following documents:

> Volume I, Summary Report - A summary of the ASIS evaluation work performed through July 1972. It includes a discussion of the factors considered in selecting candidate devices for testing, the recruitment of human subjects, the experimental techniques used, the criteria used to rate the performance of the devices, and the findings of the evaluation.

> Appendix - The appendix of Volume I provides the detailed technical data from which the results and conclusions of this volume were drawn. Included are summaries of the data obtained, descriptions of the methods used and the analyses employed, and the results of the analyses. Where warranted, different or more complex analyses of the data reported in Volumes II and III were performed. In a number of cases, this re-analysis uncovered errors in the original work. Where these errors were significant, the results of the re-analysis are reported

Volume II, Instrument Screening Experiments - Details of the experiments conducted for TSC by the Guggenheim Center, Harvard School of Public Health.

Volume III, Instrument Performance at High BAL - Results of the experimental work performed for TSC by Dunlap and Associates, Inc.

The authors would like to acknowledge that much of the success of this program is due to the efforts of the above organizations and of many individuals. Specifically, much of the original conception of the program and its overall management were the contribution of P.W. Davis. Design and construction of the TSC interlock units were carried out by A. Warner. Aid in the analysis of the data contained in Volume I was provided by J. Nardone, B.A. Kolodziej, and B. Major. Patient computer programming and data processing were contributed by D. Ofsevit.

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT.)

LIST OF ILLUSTRATIONS

LIST OF TABLES

1. INTRODUCTION

This report describes the Alcohol Safety Interlock System Program currently underway at the Transportation Systems Center (TSC) of the U.S. Department of Transportation. The program is sponsored by the Office of Driver Performance of the National Highway Traffic Safety Administration, in support of the NHTSA Office of Alcohol Countermeasures.

The program was designed to determine the efficacy of systems intended to automatically deny intoxicated drivers the use of their automobiles. The approach involved obtaining or developing candidate systems, evaluating the more promising ones in laboratory tests, and, if warranted, field-testing them.

This report is concerned with those investigations of Alcohol Safety Interlock Systems taking place from mid-1970 through mid-1972. The investigations described include a review of extra-governmental responses to a DOT prospectus, a survey of pertinent literature, and laboratory tests performed under contract to the Transportation Systems Center by the Guggenheim Foundation for Aerospace Health and Medicine of the Harvard School of Public Health, and by Dunlap and Associates Incorporated.

2. ASIS CONCEPT

As part of its program to develop methods of reducing the number of alcohol-related traffic accidents, the U.S. Department of Transportation (DOT) is investigating the efficacy of Alcohol Safety Interlock Systems (ASIS). As currently envisioned, these systems are intended to perform two functions:

a. Automatically determine whether the driver is intoxicated.

b. Prevent the driver from operating his vehicle if he is intoxicated.

For the purposes of this report, the term "intoxicated" refers to the physiological and psychological condition of a person with a blood alcochol level (BAL) equal to or greater than 0.10% wt./vol. The term "sober" refers to the state of an individual with a BAL equal to or less than 0.03%. A person is considered functionally impaired when his BAL is between 0.03% and .10%.

2.1 ASIS CLASSIFICATION

Alcohol Safety Interlock Systems are classified according to the method they use to establish intoxication.

2.1.1 Chemical ASIS

Instruments in this class estimate BAL through measurements of the alcohol content in the breath, tissues, body fluids, or wastes. Many law-enforcement agencies measure alcohol present in exhaled alveolar air. The technique is attractive because the test is specific to alcohol, a breath sample is relatively easy to acquire (compared to blood and urine samples), and the result is a quantitative measure which is acceptable as evidence in a court of law.

During the period covered by this report, no ASIS using chemical or electrochemical tests of exhaled alveolar air to determine intoxication were available for evaluation. Research into electrochemical sensors suitable for ASIS was undertaken by TSC and by several commercial organizations, and suitable sensors are expected to be available for testing and evaluation as part of the ASIS program in the near future. Providing that they meet prior laboratory criteria for factors such as sensitivity, stability, and repeatability, these chemical ASIS will be mainly field-tested in this program.

2.1.2 Performance ASIS

A second class of techniques uses the measurement of performance or behavior in psychomotor tasks. This method requires the establishment of a baseline performance level for a sober driver. A reduction in performance below this criterion is taken to indicate intoxication. Conceivably, two types of performance ASIS could be developed: hurdle ASIS, for which the test of performance is taken before the vehicle can be driven, and continuous-monitoring ASIS, for which the performance of the driver is measured during an extended period while the vehicle is being driven.

Hurdle ASIS are quite simple in operation, and may be easily interfaced with existing vehicle designs. However, since a hurdle ASIS determines intoxication in a relatively short test, drivers might be able to pass it by marshaling their abilities for a brief period, although their performance level over longer periods could be quite low. Also, hurdle ASIS could allow a person to start a car immediately after drinking a large quantity of alcohol, since performance degradation might not develop until some time had elapsed. Similarly, hurdle ASIS are not useful in cases where the driver begins drinking after he has started to drive.

A continuous-monitoring ASIS would in theory be responsive to driving performance, the variable of prime interest. It could monitor actual driving behavior, and would be sensitive to any factor which produced a performance decrement. To develop such an ASIS, it would be necessary either to have a metric representing safe driving or to identify some critical aspect of the driving process which is affected by intoxication. In either case, a normal baseline would have to be established for the entire population. Since no such metric is yet available, and as no aspect of the driving task has been demonstrated to be reliably affected by intoxication, performance-type continuous-monitoring ASIS are presently impractical.

2.2 SOURCES OF INFORMATION

In order to acquaint commercial and academic organizations with DOT's interest in ASIS development, and to ensure that all possible ASIS techniques would be considered, the National Highway Traffic Safety Administration issued a prospectus entitled "Some Considerations Related to the Development of an Alcohol Safety Interlock System (ASIS)" in October of 1970. The prospectus was sent to organizations which had previously responded to an announcement in the Commerce Business Daily, or had otherwise expressed interest in this topic. It contained discussions of the need for an ASIS, the various possible techniques available, and the potential problems inherent in the development of an ASIS.

A letter accompanying the prospectus requested (a) descriptions of potential ASIS, (b) discussion of the possible solutions to the problems mentioned, and (c) description of the responding firm's experience and capabilities in this area. Some 25 organizations responded to the prospectus. Their responses were analyzed in conjunction with a general survey of the literature pertaining to various kinds of performance degradation induced by alcohol.

2.3 SELECTED TECHNIQUES

Most of the responses contained some of the following: a description of an ASIS developed by the respondent, a description of a potential solution or solutions to the problems, and comments on the problems raised in the prospectus. The responses are discussed in detail in a document entitled "Summary and Evaluation of Responses Received on the Alcohol Safety Interlock System Prospectus."* Because of the proprietary nature of the material discussed, the distribution of this report has been limited to the Government. A brief discussion of the nonproprietary aspects of the most appropriate suggestions is presented below, together with the information gleaned to date from a continuing review of literature.

2.3.1 Measurement of Alcohol in the Breath

Seven of the 25 responding organizations suggested an ASIS based on the detection of alcohol in body tissues, wastes, or breath. In general, the suggestions which dealt with tests on tissue or wastes were neither detailed nor specific. With regard to breath-based tests, two firms suggested devices which were far too expensive to be seriously considered for adoption in a large-scale ASIS program. One source described a gas chromatograph which was estimated to cost several thousand dollars in its then-current form.

Two other sources suggested the use of a sensor based on a catalytic-absorption or catalytic-oxidation process. This technique was expected to have a sensitivity in the range of 300 parts per million (ppm), and thus would be suitable for testing alveolar air.

Suggestions for measures to counteract user attempts to deceive this type of device revolved around a multisensor approach, which would require not only the absence of alcohol in a breath sample of the proper temperature, but also the presence of the gases normally found in alveolar air (CO_2 and H_2O) in the expected quantities. This technique is intended to make the substitution of some other air supply difficult.

2.3.2 Measurement of Performance on a Divided-Attention Task

Seven of the responding organizations suggested that ASIS be based on the measurement of performance on a divided-attention

*DOT Report DOT-TSC-NHTSA-71-2, May 1971 task. A review of the literature revealed evidence that such a technique might be usable. Moskowitz and DePry[1] demonstrated a decrement in the performance of intoxicated subjects over sober ones on a two-task, auditory divided-attention problem, though no decrease in performance was observed on either of the component tasks when they were presented separately.

Though the technique described by Moskowitz and DePry appears to be useful in discriminating between sobriety and intoxication, an auditory-type divided-attention task may not be practical for this particular job. The overall magnitude of the effect at the low BAL's tested (.07% to .08%) was small. However, Moskowitz and DePry reported a 14% increase in error rate over sober performance for a given individual at moderately high (.07% to .08%) BAL's, implying that determination of the within-and between-subject variability in performance will be a major factor in assessing the usefulness of the technique.

The General Motors Corporation response described an ASIS that measured performance on a divided-attention task, which requires rapid memorization of a five-digit display and rapid keyboard entry of the number. During keyboard entry, the driver's attention is momentarily diverted by a visually presented command for a brake-pedal response. This ASIS was obtained from GM; the results of a laboratory evaluation are discussed in the appendix.

A third type of divided-attention task, requiring simultaneous performance of a two-choice complex-reaction task and a tracking task, was developed and fabricated by TSC for evaluation as an ASIS. Both tasks utilize visual stimuli and manual responses. This device was tested in the laboratory evaluation programs; the results are discussed in the appendix. This divided-attention task was later revised and a complex-reaction task which required response to stimuli in the visual periphery substituted. This revised device is expected to be included in the next scheduled laboratory evaluation.

Performance on a divided-attention task as a measure of intoxication may have some inherent drawbacks; in general, the component tasks are necessarily not simple, and successful performance of the resulting complex task may require extensive training, or even be beyond the sober ability of many of those driving.

2.3.3 Measurement of Pursuit-Tracking Task

Four respondents proposed measurement of performance on a Pursuit-Tracking Performance Task as an ASIS technique. Pursuit-tracking tasks require the positional matching of a moving element controlled by a random, pseudorandom, or preprogrammed forcing function with an element controlled by the test subject. Pursuit tracking has long been used as a standard task in psychomotor assessment programs, since performance is a function of the operator's hand steadiness, control precision, and ability to predict the target's future position. Furthermore, the tracking is similar to one of the types of performance necessary for driving.

Laboratory studies described in the response of the Highway Safety Research Institute indicated that significant decrements in various performance measures of a pursuit-tracking task occur at BAL's as low as 0.05%. Since no commercially developed ASIS use this technique, the Transportation Systems Center developed and fabricated a single-axis, position-controlled pursuit-tracking task. This device was included in the laboratory evaluation; the results are discussed in the appendix.

2.3.4 Measurement of Performance on a Compensatory-Tracking Task

While compensatory-tracking was suggested by only one respondent, there is evidence in the scientific literature that performance on such a task is affected by the ingestion of alcohol. In laboratory studies, degradations in compensatory-tracking performance due to alcohol intoxication have been observed by Mortimer[2] and Gibbs[3].

Compensatory tracking tasks require the centering of a moving element which is driven by a random, pseudorandom, or preprogrammed forcing function. Performance on a compensatory-tracking task depends on the operator's response latency, decision latency, control precision, and vigilance. The task is easily learned and has often been used to assess psychomotor performance.

No ASIS based on this technique was commercially available at the beginning of the laboratory evaluation. TSC developed and fabricated a one-degree-of-freedom, position-controlled compensatory-tracking task. The results of the laboratory evaluation of this device are discussed in the appendix. After the first phase of the laboratory evaluation had begun, the Raytheon Company developed a candidate ASIS called the Reaction Analyzer, which requires the subject to maintain equal brightness on a pair of lights which represent the relationship between the manual control (a potentiometer) and an undisclosed driven element. This device was included in the second phase of laboratory evaluation. The results are discussed in the appendix. A second-generation version of the Raytheon Reaction Analyzer is expected to be included in the next scheduled laboratory evaluation.

2.3.5 Measurement of Performance on a Simple-Reaction-Time Task

Three respondents suggested an ASIS based on measurement of simple-reaction time. In simple jump-reaction tasks, the subject is required to make a simple motor response as quickly as possible after the occurrence of a stimulus. Only one specific stimulus occurs and only one type of response is required. Testing of jump-reaction time is easy, and has good face validity for determining driving ability.

The Nartron Corporation described a device (Safelock) which uses the individual's jump-reaction latency to determine whether the driver is sober or intoxicated. The assumption in this design is that intoxication will result in a high response latency. A second device, developed by Robert D. Smith (QuicKey), compares the reaction time of an intoxicated individual with his previously determined sober response level. The device is calibrated to the user, and from this calibration a response latency band is established. An individual who responds significantly more slowly than the calibration score is assumed to be intoxicated, and fails. Responses which are considerably faster than the calibration are considered indicative of an attempt to circumvent the test by substituting another individual, a chance response, or evidence of erratic performance.

Since both devices measured the same type of performance, and the QuicKey was described as being sensitive to both increased latency and increased variability of latency, only the QuicKey was included in the laboratory evaluation. The results of the evaluation are discussed in the appendix.

2.3.6 Measurement of Steadiness, Dexterity, or Control Precision

Three respondents mentioned changes in hand steadiness, dexterity, or control precision as an ASIS technique. Previous laboratory experimentation on the effects of intoxication on this type of performance measured tracking-type tasks, confounding tracking and steadiness. Therefore, it was decided to evaluate an ASIS device which used this principle. One of the three respondents, A.S. Dwan, Ltd., constructed an ASIS candidate based on this technique. The device, a Prototype Theft Lock, requires considerable precision and hand steadiness to fit the key into the lock and turn it to the start position. The device was included in the laboratory evaluation; the results are discussed in the appendix.

2.3.7 Measurement of Critical Flicker-Fusion Frequency

Two respondents suggested that a measurement of the effects of alcohol on flicker fusion be considered as an ASIS technique. The technique has the disadvantage that measurements of flicker fusion are known to be sensitive to variables other than alcohol, such as ambient light, fatigue, and illness. However, the technique is simple and uses an easily learned task.

One of the respondents, Creare, Inc., constructed a device utilizing this effect to detect intoxication. In practice, the driver is required to indicate whether the target is flickering or steady. If the driver is incorrect on more than some preset number of trials, he is considered intoxicated. This device was included in the laboratory evaluation; the results are discussed in the appendix.

2.3.8 Measurement of Response Coordination

Two respondents suggested measurements of response coordination as an ASIS technique. One organization, TDL, described a device, the Drunk-Driver Eliminator (DDE), which they have developed as a candidate ASIS. In operation, the driver performs a simple sequential key/brake-pedal task. The driver must turn the ignition key and then immediately depress the brake pedal. A long response latency or inversion of the order of movements is taken to indicate intoxication.

The ASIS described by TDL appears to be simple, very inexpensive, and easily installed in any present vehicle. Although insufficient information was available to allow prediction of the utility of the DDE as an ASIS, the extreme simplicity of the device and its unique nature evoked interest. Therefore, the device was obtained and included in the evaluation. The results are discussed in the appendix.

2.3.9 Measurement of Performance on a Complex-Reaction Task

While no respondents suggested the measurement of performance on a complex or choice reaction task as the basis of an ASIS technique, the literature review did reveal that such performance is a simple index of information-processing capacity.[4] Biederman and Kaplan[5] have developed a sensitive version of this task, by requiring the subject to respond to some stimuli with spatially incompatible responses. Since it was considered likely that intoxication would degrade information-processing capacity, a candidate ASIS which used this task, the Complex-Reaction Tester, was designed and a prototype fabricated by TSC.

This device requires the subject to choose one of two responses to each of a set of four possible stimuli. Two of the stimulus/response combinations are spatially compatible, in that both the stimulus and the response occur on the same side (right or left) of the panel. The other two are spatially incompatible, in that the required response is on the opposite side of the panel from the stimulus.

The results of the evaluation of this device are discussed in the appendix.

3. LABORATORY EVALUATION

In order to determine the efficacy of the various ASIS devices described in Section 2, a laboratory evaluation was carried out. It included pilot studies, instrument-screening tests, and testing to establish BAL/performance relationships.

3.1 PILOT STUDIES

Research in this segment of the evaluation served to establish adequate procedures for subject recruiting, handling, safety, training and performance testing, alcohol exposure, and alcohol-level determinations. Subjects represented two basic groups: social subjects (paid volunteer drivers of at least 21 years of age) and Registry subjects (drivers convicted of driving while intoxicated, identified through lists prepared by the Massachusetts Registry of Motor Vehicles).

In Massachusetts, at the time of the study, individuals were rarely convicted of driving while intoxicated if they had BAL's of less than 0.18%. Therefore, it was expected that the Registry subjects would be experienced and heavy drinkers. This was borne out in the laboratory evaluation.

Subjects were required to practice intensively on all devices until they had reached a predetermined performance criterion or had completed a preset number of trials.

Subjects ingested low-congener alcohol mixed with fruit juice in quantities calculated to reach average peak alcohol levels ranging between 0.10% and 0.22%.

Blood alcohol was determine by measuring exhaled alveolar air with a Stephenson Breathalyzer calibrated with Nalco prepared standard samples. The measure was termed a Breath Alcohol Equivalent (BAQ) to the BAL.

3.2 INSTRUMENT SCREENING TESTS*

3.2.1 Devices Selected

On the basis of the prospectus responses, review of pertinent literature, examination of available candidate ASIS devices by TSC staff, and information gathered during the pilot studies, the following devices were selected to undergo laboratory screening tests. Devices were obtained through loan, lease, or purchase.

PROTOTYPE THEFT-PROOF LOCK - Developed by A.S. Dwan, Ltd., this unit is an ignition lock which requires the driver to carefully set a numbered combination and insert the ignition key with precision. If the driver sets the combination incorrectly, is clumsy in inserting the key, or exceeds the time allowed on the task, he is prevented from starting his vehicle.

CRITICAL FLICKER-FUSION TESTER - Developed by Creare Incorporated, this requires the operator to discriminate between flickering and steady visual stimuli in order to start his vehicle. The device's ability to determine intoxication is dependent upon a reduction in the critical flicker-fushion frequency which accompanies intoxication.

PHYSTESTER - Developed by the Delco Electronics Division of General Motors, this unit requires that the driver perform a divided-attention task to start his vehicle. The driver must first enter a combination on a touch-tone-type keyboard. If he does this correctly, a random five-digit number is displayed. The driver must rapidly memorize this number and enter it on the keyboard. At some time during this process a visual stimulus signaling a required brake application will appear on the display. The subject must promptly depress the brake pedal while continuing to enter the number. Failure to perform any

*The testing described in this section was performed by the Guggenheim Center for Aerospace Health and Safety, Harvard School of Public Health, Boston, MA, under Contract DOT-TSC-213.

of those steps in the time alloted is taken to indicate intoxication.

QUICKEY - Developed by Robert D. Smith, this unit requires the driver to provide a simple reaction response to visual stimuli. For each subject, a characteristic response latency for the QuicKey is established. This response latency is used to set a passing band such that only a latency which is within ten percent of the characteristic response latency will allow the subject to pass. Responses which are either slower or faster than required by the band limits cause failure. This device determines intoxication through the detection of both increased response variability and increased response latency.

DRUNK-DRIVER ELIMINATOR - Developed by the TDL Group of Companies, this unit requires the driver to make closely coordinated and sequenced manual and pedal responses. Responses too widely separated in time, or inverted in sequence, are considered to indicate intoxication.

The reivew also revealed a number of principles which might be suitable for an ASIS, but had not been tried out. Three ASIS prototypes were developed by TSC to allow testing of these principles. The following paragraphs briefly describe these TSC-developed units.

COMPENSATORY-TRACKING TESTER - This unit requires the driver to perform a compensatory-tracking task. If the driver's absolute-error score exceeds a pass/fail threshold, he cannot start his vehicle. The threshold is set individually for each driver.

PURSUIT-TRACKING TESTER WITH SECONDARY DETECTION TASK - This device requires the driver to perform a pursuit-tracking task and simultaneously respond promptly and correctly to a pair of visual stimuli. If the driver's tracking score shows error above a preset threshold, or if he responds too slowly or incorrectly to the visual stimuli, it is taken as an indication of intoxication.

COMPLEX-REACTION TESTER - This unit requires the driver to perform a complex-reaction task which has both compatible and incompatible stimulus/response combinations. The driver is presented with a four-stimulus display. The stimuli are composed of four lights arranged as the corners of a rectangle. The display stimuli form two vertical pairs, since the horizontal dimension of the vehicle is much greater than the vertical. The driver must respond to stimuli in the upper corners by pressing the button on the same side as the stimulus. (This is considered a compatible or same response.) The driver must respond to stimuli on the lower corners by pressing the button on the opposite side of the rectangle from the stimuli. (This is considered an incompatible or opposite response.) Slow or incorrect responses are taken to indicate intoxication.

3.2.2 Procedure

The screening tests were designed to determine the accuracy with which the techniques embodied in the candidate devices measured intoxication. For these tests social subjects and Registry subjects, as described earlier, were trained in the operation of each candidate device over a period of 1 to 3 days, depending on the device. Subjects were then tested at various blood-alcohol levels on each of the devices.

The tests were conducted in the following manner. After entering the experimental area, subjects were tested for BAQ, and initial tests were made of their performance on the ASIS devices they had been trained on. Next, experimental subjects received neutral spirits alcohol mixed with the fruit juice of their choice. Control subjects received fruit juice alone. Twenty minutes later, testing on the candidate devices was resumed; it continued for approximately 40 minutes. Midway in the 40-minute period, a BAQ determination was made. Exactly one hour after the administration of the first drink, the second drink was administered. Twently minutes later, performance testing resumed, with BAQ determined midway in the testing period. One hour after the second drink, a third was administered and the cycle repeated. The peak alcohol levels (approximately 0.11% BAQ) were reached after the third drink. For the next three hours no alcohol was administered, but the performance testing and BAQ determinations were continued. The experimental design is discussed in detail in the appendix.

3.2.3 Results of Screening Tests

The purpose of these experiments was to determine how closely the subject's performance on each candidate device correlated with blood alcohol level. Pearson-product-moment coefficients of correlation (r) between an appropriate index of subject performance and the BAQ for each subject at the time of the performance were calculated for each device. The devices were then ranked in terms of the magnitude of the r calculated. Tests of statistical significances were made for each coefficient to determine whether the difference between the computed coefficient and a coefficient of zero (no correlation) were due to chance variation or to the number of statistical tests performed. Credence was given only to coefficients of correlation associated with probabilities of being due to chance of less than or equal to .01 ($P \leq .01$). The following correlation coefficients between test performance and BAQ were calculated:

Prototype Theft Lock	R = 0.156*
Critical Flicker-Fusion Tester	R = 0.107*
Phystester	R = 0.393***
QuicKey	R = 0.343***
Drunk-Driver Eliminator	R = 0.045*
Compensatory-Tracking Tester	R = 0.329**
Pursuit-Tracking Tester with Secondary Task (Tracking Accuracy)	R = 0.392***
Complex-Reaction Tester (Errors)	R = 0.153**

*$P > .05$
**$P \leq .01$
***$P \leq .005$

3.2.4 Selection of Devices for Future Testing

Devices were selected for future testing on the basis of the following factors: 1) the observed correlation between subject performance and BAQ; 2) the extent of preinstallation driver training required for successful use of the device; 3) whether the intrinsic design of the device required determination of a pass/fail threshold for each driver, or a single universal threshold could be set for all drivers; 4) the relative cost/complexity of the device. (This last criterion was used only to discriminate between the Pursuit-Tracking Tester with Secondary Task and the Compensatory-Tracking Tester, since these devices had similar coefficients of correlation but the design of the Pursuit-Tracking Tester with Secondary Task was considerably more complex.)

The following four devices were chosen:

Compensatory Tracking Tester: R = 0.329; considerable training required, individual threshold required, cost/complexity low.

QuicKey: R = 0.343; moderate training required, individual threshold required, cost/complexity moderate.

Complex Reaction-Time Tester: R = 0.153; little training required, universal threshold, cost/complexity moderate.

Phystester: R = 0.393; considerable training required, universal threshold, cost/complexity high.

The Prototype Theft Lock, Critical Flicker-Fusion Tester, and the Drunk-Driver Eliminator were dropped because the correlation of the performance indices with BAQ was very low. Further testing of the Pursuit-Tracking Tester with Secondary Task was postponed until a more thorough examination of divided attention tasks could be made.*

3.3 PASS/FAIL EVALUATION

This series of experiments was intended to allow prediction of the range of performance in actual use to be expected from

*An improved version of this device is currently being tested.

each of the four devices selected in the screening test. The pass/fail criterion testing was performed in two series. The first, in which peak BAQ levels in excess of .10% were reached, is referred to as the Low-BAQ Series. The second, in which BAQ levels in excess of .18% BAQ were reached, is referred to as the High-BAQ Series.

3.3.1 Low-BAQ Series*

3.3.1.1 Pass/Fail Criteria

a) QuicKey - The procedure for establishing the pass/fail cutoff points from the quantitative data was provided by the manufacturer. Each subject's maximum allowable response time was the eighth fastest reaction time out of his last 50 training repetitions (the 16th percentile). His minimum permissible score was set at 15% below this value. The subject's response time during testing had to be within these boundaries in order for him to pass.

b) Complex-Reaction Tester - Subjects were allowed no more than one error (either pressing the wrong button or taking more than 0.9 seconds to respond) out of eight presentations.

c) Compensatory-Tracking Tester - The mean and standard deviation of the last 36 repetitions of training were calculated for each subject. Any score greater than the sum of the mean tracking error score plus one standard deviation was scored as a failure; any score less than or equal to this was passing.

d) Phystester - The pass/fail criterion for this device was provided by the manufacturer. Subjects had 1.5 seconds' display time to memorize the number, and had to complete the dual task of entering the five digits on the keyboard and pressing the brake pedal within 3.5 seconds in order to pass.

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*These tests were performed by the Guggenheim Center for Aerospace Medicine, Harvard School of Public Health, Boston, MA, under Contract No. DOT-TSC-213.

3.3.1.2 Procedure - Substantial monetary rewards were given to the subjects immediately after completion of each successful attempt on each device. This was done in order to simulate the kind of motivational context which is to be expected when an individual with an ASIS actually attempts to start his or her vehicle. During the Low-BAQ Series each subject was allowed three attempts or trials on the Phystester, Compensatory-Tracking Task, and Complex-Reaction Tester. However, only one trial on the QuicKey occurred during each of the seven testing blocks during the testing day. For each trial in which the subject was successful on the Phystester, Compensatory-Tracking Tester, or Complex-Reaction Tester, he received a token worth \$.50. For each successful attempt on the QuicKey, the subject received a token worth \$1.50.

The tokens were presented immediately after each trial and redeemed at the end of the series. The differential reward was due to the nature of the ASIS tasks and the time required to complete each. During a single day a subject could have earned up to \$42.00, if he had successfully completed all attempts. No subject was able to perform this well.

3.3.1.3 Results - Performance of the ASIS was gauged in terms of the percentage of no-starts recorded for the subjects at each BAQ. A no-start was recorded when an individual passed less than some proportion of successive trials at a given alcohol level. The proportion of failed trials resulting in a no-start was determined through post-hoc manipulation of the trial performance data to achieve the greatest difference in the percentage of no-starts between sober and intoxicated subjects, commensurate with a sober failure rate of less than 10%.

For the Complex-Reaction Tester, the Compensatory-Tracking Tester, and the Phystester, failure of more than one out of three trials was a no-start. For the QuicKey, failure to achieve a reaction latency within the window representing sober performance within two minutes was a no-start. Figure 1 depicts the percentage of no-starts observed for the devices tested for subjects in the following BAQ ranges: BAQ $\leq$ .03% (sober), .03% > BAQ > .10%

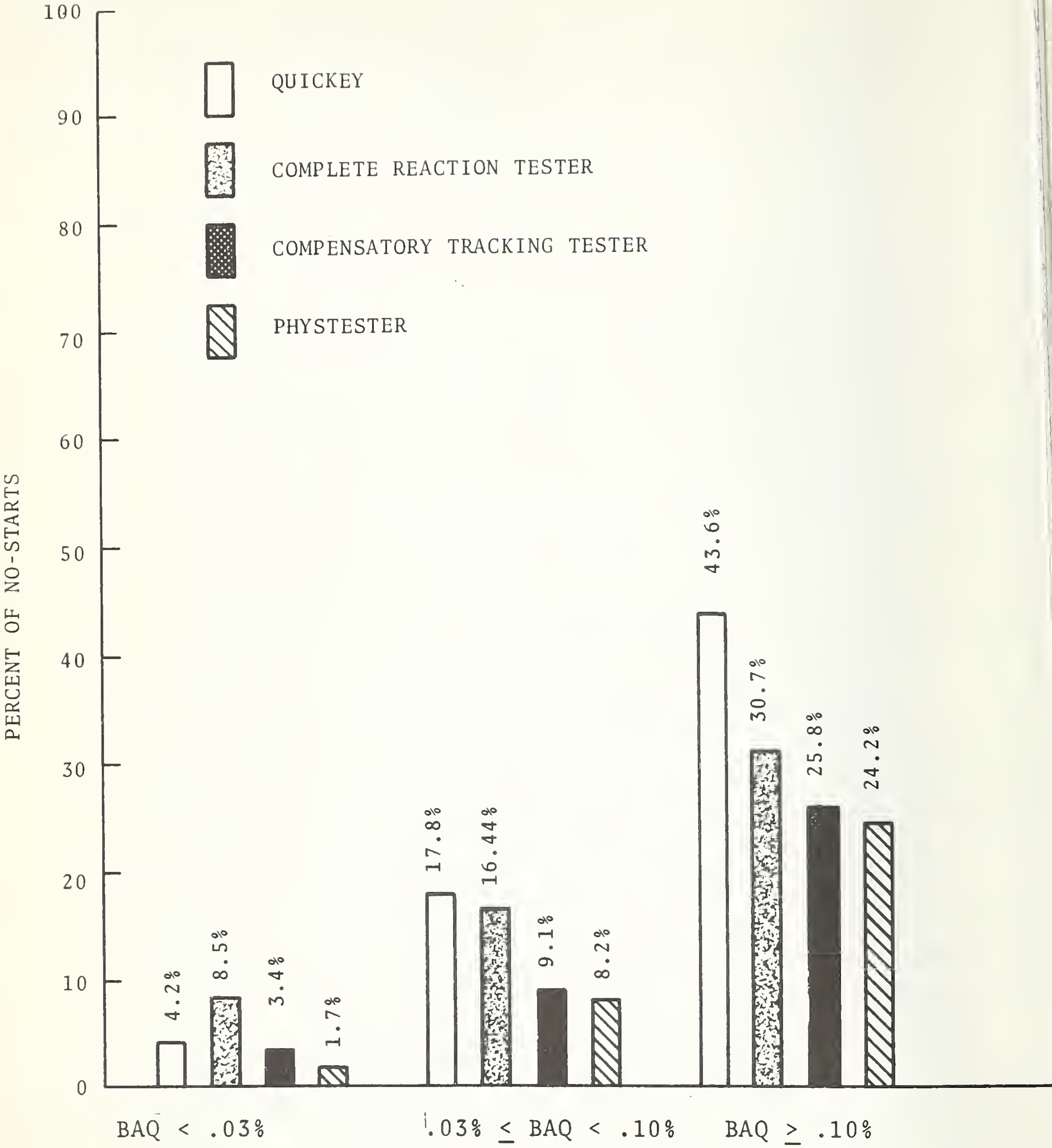

Figure 1. Percentage of No-Starts Observed in Low-BAQ Test Series

(incapacitated); BAQ $\geq$ .10% (intoxicated). As may be seen from the figure, the two devices which use universal thresholds have similar no-start differentials of 22% (the difference between the percentage of no-starts for intoxicated subjects, or correct rejections, and the number of no-starts for sober subjects, or incorrect rejections). The observed no-start differential for the two devices which require individually set thresholds are quite different. QuicKey had an observed differential of approximately 39%. The Compensatory-Tracking Tester had an observed no-start differential of approximately 22%. The devices may be ranked in terms of the observed no-start differential as follows:

QuicKey	39.4%
Phystester	22.5%
Compensatory–Tracking Tester	22.4%
Complex–Reaction Tester	22.2%

It is obvious that there was little difference between the observed no-start differential for the last three devices.

3.3.2 High-BAQ Series

3.3.2.1 Devices Tested - In the High-BAQ Series* of tests, three of the candidate ASIS devices (QuicKey, Complex-Reaction Tester, and Phystester) were evaluated using alternative pass/fail criteria and no-start criteria. The Compensatory-Tracking Tester was replaced by a somewhat different tracking task, the Reaction Analyzer (developed by Raytheon Co.). Testing was also begun, and terminated due to failure of the test unit, on a ASIS candidate device developed by the Nartron Wire Corporation.

There were a number of significant differences in the procedures used in the Low-BAQ and High-BAQ Series. Peak BAQ's in excess of .18% were reached for most subjects in the High-BAQ Series. Subjects were carefully selected on the basis of previous

*Testing in this series was conducted by Dunlap and Associates, Inc., Darian, CT under Contract DOT-TSC-251.

frequent use of alcohol and previous frequent achievement of BAQ's in excess of .15%, rather than drunk-driving convictions. Thirty-seven subjects were used (20 male, 17 female).

The payoff systems used to motivate the subjects were manipulated so as to allow sufficient flexibility to explore various pass/fail criteria and no-start strategies. These features are discussed in detail in the report prepared by Dunlap and Associates, Inc., DOT-TSC-251-4.

3.3.2.2 Procedure - The following pay schemes provided the optimum performance on the ASIS candidate devices named:

QuicKey - Subjects were allowed to make as many responses as possible during the two-minute period. \$.50 was paid for all responses falling into the window which represented a pass. A single two-minute trial was given during on each of seven blocks of the testing day.

Complex Reaction Tester - Subjects were given \$.25 per successful trial, with a total of three trials per block. Subjects were given a 100% bonus for each block of three in which they passed all trials.

Reaction Analyzer - Subjects were given \$.25 per successful trial, with a bonus of 100% if they passed all trials in the block of five.

Phystester - Subjects were given \$.25 per successful trial, with a bonus of 100% if they passed all trials in the block of five.

3.3.2.3 No-Start Strategies - The following no-start strategies provided optimum no-start differentials:

QuicKey - Less than one response in the "window" in the two-minute trial resulted in a no-start.

Complex Reaction Tester - Failure on any of the three trials resulted in a no-start.

Reaction Analyzer - Failure on any of the first three trials resulted in a no-start. (The last two trials were dropped from consideration).

Phystester - Failure on any of the first three trials resulted in a no-start. (The last two trials were dropped).

3.3.2.4 Results - Figure 2 graphically depicts the observed percentages of no-starts at four BAQ ranges: BAQ < .03% (sober), .03% ≤ BAQ < .10% (incapacitated), .10% ≤ BAQ < .18% (intoxicated), and .18% ≤ BAQ (very intoxicated).

The candidate ASIS devices may be ranked according to the optimum observed differential between sober no-starts (false rejection) and very intoxicated no-starts (correct rejection) as follows:

Phystester	60.2%
Reaction Analyzer	58.5%
QuicKey	53.4%
Complex-Reaction Tester	50.3%

Table 1 provides the observed no-start percentages for all of the devices tested both in the High and Low-BAQ test series at each of the BAQ ranges.

An obvious method of circumventing an ASIS requiring individual pass/fail thresholds is to "hold back" during training so that a spuriously low threshold will be set. This problem was investigated during the High-BAQ Series of tests. Subjects were requested to attempt to hold back, and they were generally successful. Therefore, if techniques requiring individual thresholds are used, care must be devoted to eliminating "jiggery-pokery" during the establishment of these thresholds.

Other data gathered during these experiments are relevant to the implementation of an ASIS program. As far as the drinking history of subjects is concerned, it was found that Registry

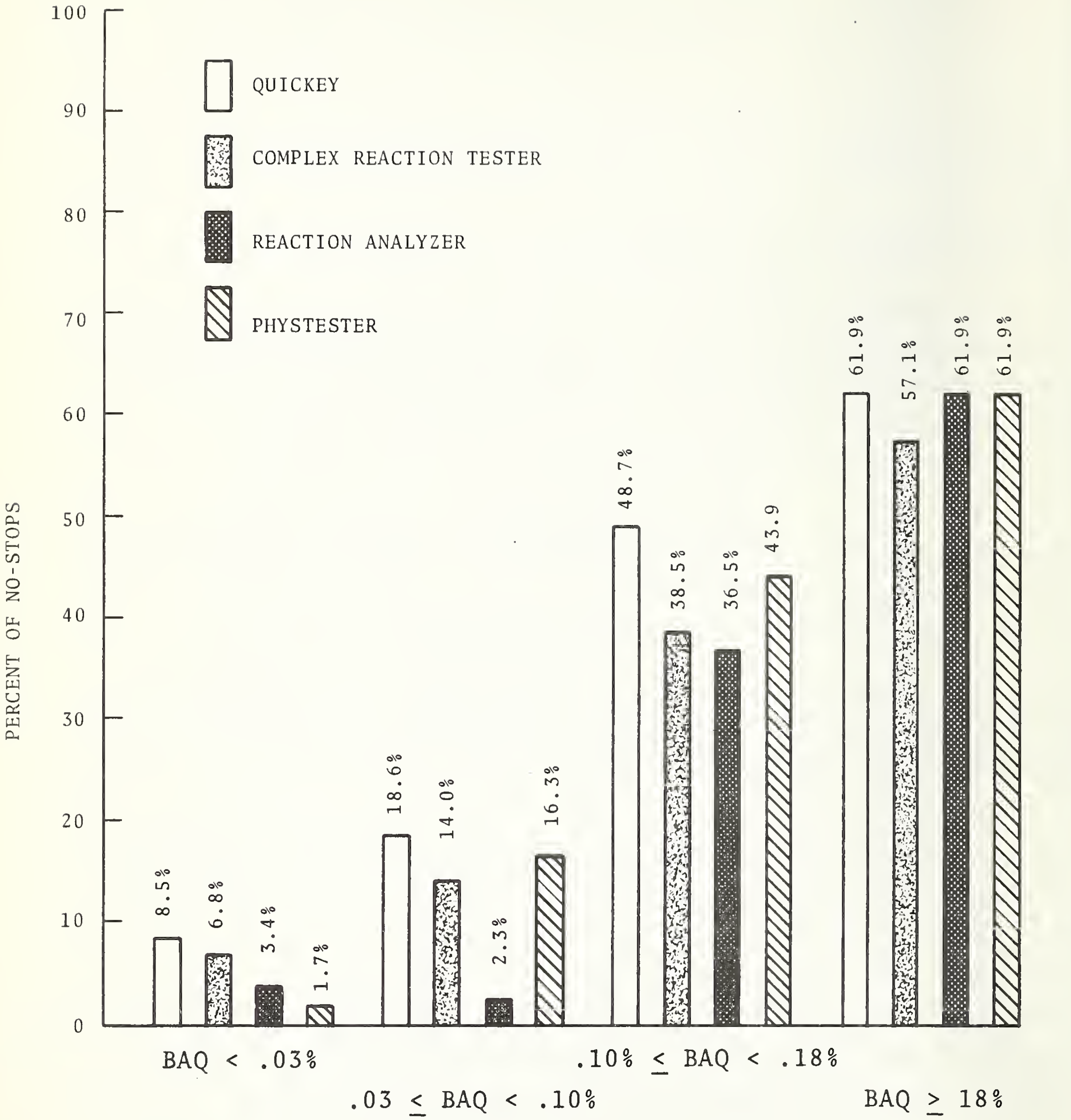

Figure 2. Percentage of No-Starts Observed in High-BAQ Test Series

TABLE 1. PERCENTAGE OF NO-STARTS OBSERVED IN BOTH BAQ TEST SERIES

a. Low-BAQ Series

BAQ Range	QuicKey	ASIS Candidate Devices		
		Complex-Reaction Tester	Compensatory-Tracking Tester	Phystester
BAQ <. 03%	4.2%	8.5%	3.4%	1.7%
.03% ≤ BAQ <. 10%	17.8%	16.44%	9.1%	8.2%
BAQ ≥. 10%	43.6%	30.7%	25.8%	24.2%
No-Start Differential	39.4%	22.2%	22.4%	22.5%

b. High-BAQ Series

BAQ Range	QuicKey	ASIS Candidate Devices		
		Complex-Reaction Tester	Reaction Analyzer	Phystester
BAQ <. 03%	8.5%	6.8%	3.4%	1.7%
.03% ≤ BAQ <. 10%	18.6%	14.0%	2.3%	16.3%
.10% ≤ BAQ < .18%	48.7%	38.5%	36.5%	43.9%
BAQ ≥. 18%	61.9%	57.1%	61.9%	61.9%
No-Start Differential	53.4%	50.3%	58.5%	60.2%

subjects (having a history of at least one arrest for driving while intoxicated) performed no better or worse than social subjects.

Gender had no statistically significant effects upon performance on any of the devices tested. The age of subjects did play a role in performance, but this was eliminated by improved training procedures. IQ scores were correlated with performance on the Complex-Reaction Tester, but this seems to be a marginally significant effect and may be an artifact.

While alternate pass/fail strategies and start/no-start criteria were explored, it was found that using different strategies or criteria simultaneously increased or decreased the number of sober and intoxicated no-starts by an essentially constant factor.

4. SUMMARY

On the basis of prospectuses from industry and a review of pertinent literature, 12 performance-type candidate ASIS were obtained and examined by DOT/TSC. Ten of these devices underwent laboratory screening evaluations designed to determine to what extent performance on each device was correlated with blood alcohol level.

The following types of performance were found to be affected by blood alcohol level:

Hand steadiness

Perception of visual flicker

Pursuit tracking

Compensatory tracking

Divided-attention performance

Manual jump-reaction response

Manual complex-reaction response

Five devices underwent further laboratory testing to determine the percentage of prevented starts which could be expected at various blood-alcohol levels. The best discriminator was a divided-attention task. With this task, no-start rates of .17% for sober subjects and 61.9% for the same subjects when very intoxicated (BAQ $\leq$ .18%) were recorded.

REFERENCES

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2. Mortimer, R.G., "Effect of Low Blood-Alcohol Concentrations in Simulated Day and Night Driving", <u>Perceptual and Motor Skills</u> <u>17</u>, 399-408, 1963.

3. Gibbs, C.B., "Effect of Minor Alcohol Stress on Tracking Skill", <u>I.E.E.E. Transactions on Human Factors in Electronics</u>, Vol HFE-D (No. 4), 1966.

4. Smith, E.E., "Choice Reaction Time: An Analysis of The Major Theoretical Positions," <u>Psychological Bulletin</u> <u>69</u>, 77-110, 1968.

5. Biederman, I., and Kaplan, R., "Stimulus Discriminability and SR Compatability," <u>Journal of Experimental Psychology</u> <u>85</u>, 434-439, 1970.

APPENDIX:

DESIGN AND RESULTS

CHARLES N. ABERNETHY III

A-1, PILOT STUDIES

A-1.1 SUBJECT RECRUITMENT

Male and female subjects were selected so as to include as wide a range of age (over 21), intelligence, and occupation as possible. Their alcohol-related driving experience fell into one of two categories:

(1) "problem drinkers" (having been arrested at least once for driving while intoxicated)

(2) "social drinkers"

A-1.2 SUBJECT HANDLING

Volume II presents the details of subject handling: feeding subjects, getting them to drink and perform tasks on schedule, and dealing with them as they became intoxicated (or sick).

A-1.3 SUBJECT SAFETY

The subjects were monitored by a physician during their exposure to alcohol. After testing, they were not allowed to leave until their BAQ level had dropped below at least 0.05%. They were not permitted to drive themselves home at that level of intoxication, but were paid to go either by taxi or with a friend.

A-1.4 TRAINING AND PERFORMANCE TESTING

Details of the scheduling and motivation schemes used can be found in Volume II. Subjects had to be trained on the devices for several days before their learning curve reached a plateau. All subjects were paid a base rate plus an incentive bonus each time they passed a test. This incentive was intended to provide motivation similar to that of a person actually trying to start a car.

A-1.5 ALCOHOL EXPOSURE

During the testing sessions, subjects were given drinks of 95-proof ethyl alcohol mixed with the fruit juice of their choice. The alcohol dosage was calculated with Widmark's formula[1] from the body weight of the individual. Apparently this formula underestimated the amount of alcohol needed, however, since the target BAQ levels were generally not reached. Also, it was found that to avoid nausea, the level of the first dose had to be lower than those of the later ones.

A-1.6 ALCOHOL LEVEL DETERMINATIONS

The subjects' blood alcohol levels were estimated by means of the Breathalyzer (Stevenson Corp., Redbank, N. J.). The procedures used are described in detail in Volume II.

A-2. INSTRUMENT SCREENING TESTS

A-2.1 PROCEDURE

Subjects were trained on each device, according to a schedule, until they reached the performance criterion set for it. Each experimental subject was tested first in a pre-alcohol control condition, then one half hour after each of the three drinks (spaced an hour apart), and then at 1, 2, and 3 hours after the drink-3 test, to monitor performance at decreasing blood alcohol levels. Similar tests were performed on a smaller number of control subjects, who received non-alcoholic beverages.

All subjects were given monetary rewards as motivation for both cooperation and performance while under alcohol. Section A-2.3 discusses the specific training schedules, pass/fail criteria, testing, administration of drinks, recording of BAQ's and bonus criteria for each device. Table A-1 shows the general design of the experiment.

TABLE A-1. GENERAL EXPERIMENTAL DESIGN

Device	Control	Drink			Check		
Subjects	C	1	2	3	1	2	3
Male Social	1....K	1...K	...K	1...K	1...K	1...K	1...K
Male Registry	1....K	"	"	"	"	"	"
Male Control	1....K	"	"	"	"	"	"
Female Social	1....K	"	"	"	"	"	"
Female Registry	1....K	"	"	"	"	"	"
Female Control	1....K	"	"	"	"	"	"

For 1 through K repetitions within each testing condition.

During the training period, each subject completed a Wesman Personnel IQ test[2] and a questionnaire on drinking/driving habits, alcohol-related health and psychological problems, and drunk-driving arrests and convictions. Age, weight, and sex were also recorded.

A-2.2 DEVICES SELECTED

On the basis of previous evidence demonstrating high correlations of blood alcohol level and performance on various tasks as reported in the literature, the following devices were selected to undergo laboratory screening tests for suitability as ASIS devices. (The devices were obtained through loan, lease, or purchase, or were constructed at the Transportation Systens Center.)

Prototype Theft Lock	A. S. Dwan, Ltd.
Critical Flicker-Fusion Tester	Creare, Inc.
Phystester	Delco Electronics (Div. of General Motors)
Quickey	R. D. Smith
Drunk-Driver Eliminator	TDL Group of Companies
Compensatory-Tracking Tester	TSC
Pursuit-Tracking Tester with Secondary Detection Task	TSC
Complex-Reaction Tester	TSC

The task and responses measured for each device are described in Section A.2.3.

A-2.3 DESCRIPTION OF DEVICES & RESULTS OF SCREENING TESTS

This section describes the subject's task and the responses measured for each device. The performance of drinking (alcohol) and control (non-alcohol) subjects are summarized in a section for each device separately. For each testing condition, the mean BAQ attained, the mean and standard deviations of the performance scores (assuming a normal distribution, which frequently was not the case in actuality), and the total number of data points are listed. The Pearson-product-moment correlation coefficient for each group of subjects, and comments on the training scehdule and motivational scheme, are included.

The deviations of performance scores for drinking and control subjects are compared. Normally, both groups should perform equally well on the first test (pre-alcohol); the performance of the drinking subjects should then deteriorate increasingly in comparison to that of the controls over the drinking period, but should return to the control level during the last, non-drinking period. Both sets of scores should finish at the initial control level, but factors such as fatigue or boredom could lower the latter scores, while continued learning could raise them. This could also happen to the drinking group.

Analyses of variance were done for drinking groups' results, to determine whether the testing conditions or repetitions within testing conditions affected the subjects' performances. (Post-hoc tests were done to determine which testing conditions differed.) Lastly, a plot of the performance scores on each device as a function of BAQ is presented together with a regression line. The regression line is bracketed with lines enclosing 80% of the data points to indicate the amount of dispersion inherent in the data. The coefficient of correlation and its statistical significance are also reported for each device.

A-2.3.1 Prototype Theft Lock

A-2.3.1.1 Description of Subjects' Task on the Device-A. S. Dwan Ltd.[3] has developed a prototype theft-resistant lock whose operation requires considerable hand steadiness, dexterity, and control precision. The user must set a numbered combination and precisely insert the ignition key within a 15-second period. If the operator sets the combination incorrectly, is clumsy in inserting the key, or exceeds the time allowed, he is prevented from starting his vehicle. The device is completely mechanical. Once the key has been inserted, the driver does not have to take the test again even if the vehicle stalls. Since the device is also intended as an anti-theft measure, no override provision is included.

Responses were measured in terms of the time (in seconds) required by the subject to respond correctly. For example, a subject might start a trial, perhaps set the combination incorrectly or be clumsy in inserting the key, and fail; he would then start again and perform the task correctly. This total time was recorded.

A-2.3.1.2 Results - Subjects repeated the task five times for each of the seven testing conditions. Table A-2 lists the mean BAQ attained, mean time to complete the task, standard deviation (assuming that the distribution was normal, which was not the case), and the number of data points per cell. The correlation coefficients of BAQ by performance are shown, along with their level of significance for each group of subjects. (Note that control subjects received no alcohol.) Finally, the training criterion and the motivational scheme used during testing are listed.

Mean times-to-completion as a function of testing conditions for six female social drinking subjects and one female social control subject are plotted in Figure A-1. Results for the 17 male social drinking subjects and the five male social control subjects are given in Figure A-2.

A summary of an analysis of variance (see Volume II) for the male social subjects is reported in Table A-3. This analysis showed that the testing conditions [$F(6,96)= 4.76$, $p<0.01$] and repetitions within each trial [$F(4,64= 262$, $p<0.05$] were statistically significant. A Tukey wholly-significant-difference (WSD) test after analysis of variance showed that although the mean of the drink-2 condition reflected the slowest performance by subjects, the drink-2 condition did not differ significantly from the means of either the drink-3 or the check-2 condition. The mean performance level obtained during the drink-3 condition differed only from the check-3 condition.

An analysis of variance on the six social female subjects did not show any significant results. A summary of this analysis is presented in Table A-4.

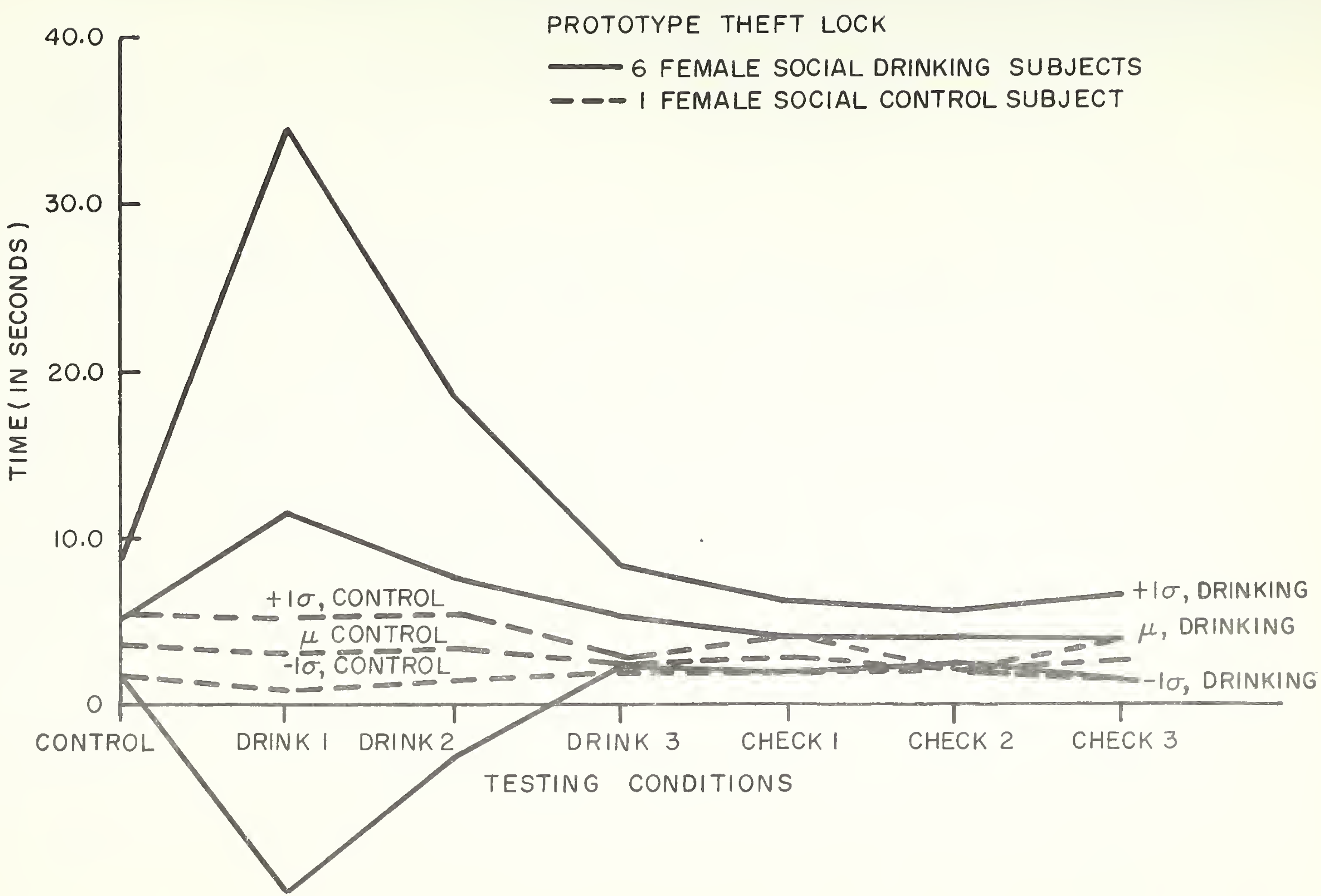

Figure A-1. Performance on the Prototype Theft Lock Device as a Function of Testing Conditions for Six Female Social Drinking Subjects and One Female Social Control Subject

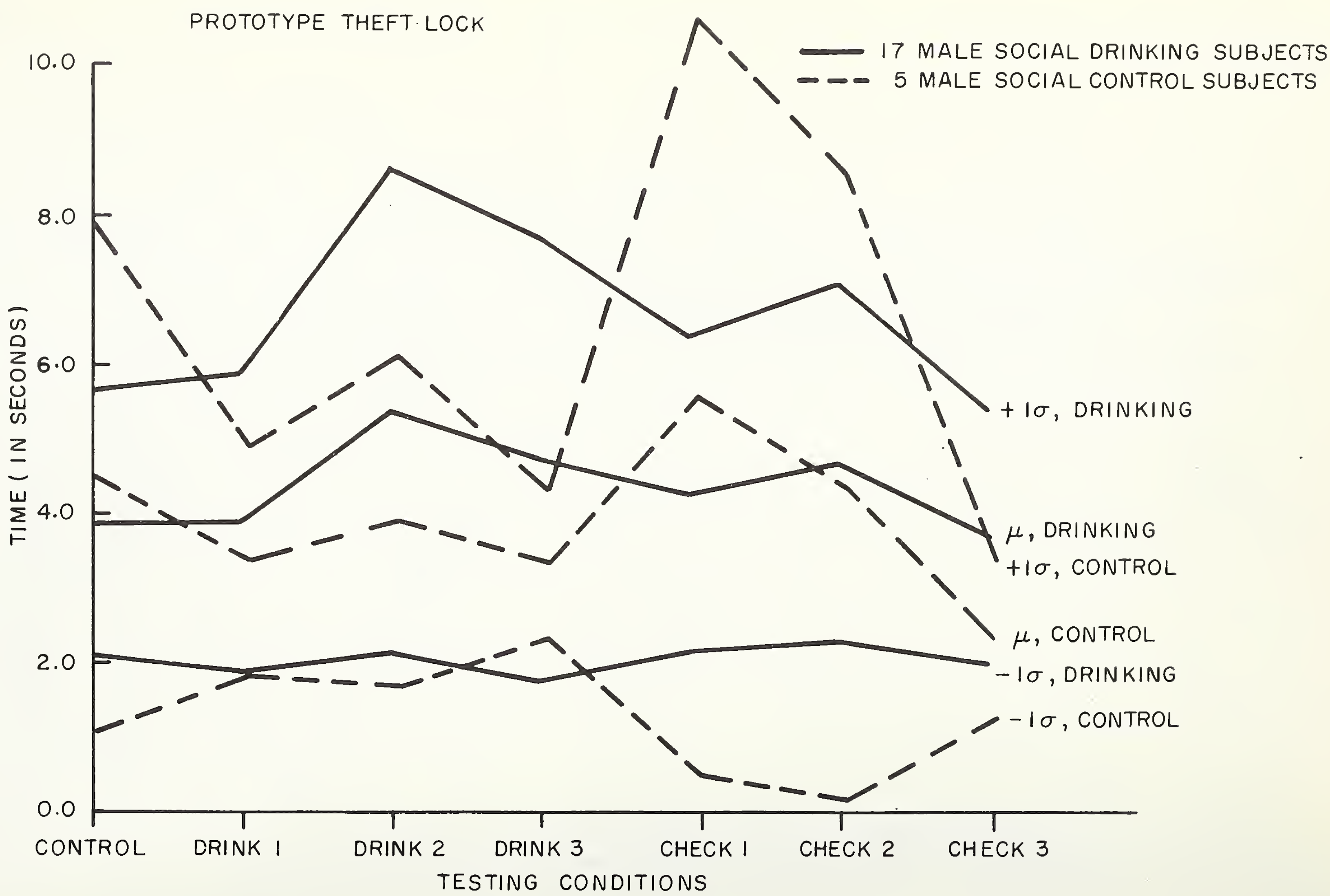

Figure A-2. Performance on the Prototype Theft Lock Device as a Function of Testing Conditions for the 17 Male Social Drinking Subjects and the Five Male Social Control Subject.

TABLE A-2. SUMMARY OF PERFORMANCE ON THE PROTOTYPE THEFT LOCK DEVICE

A.S. DWAN	DAY 1	DAY 2 - TESTING PERFORMANCE (IN SECONDS) SUBJECTS PERFORMED 5 REPETITIONS WITHIN EACH TESTING CONDITION)								
Type + No. of Subjects	Training	Control	Drink 1	Drink 2	Drink 3	Check 1	Check 2	Check 3	Correlation of BAQ and Performance + No. of Subjects	Motivation (Bonus Money)
Social Male (17)	Minimum of 20 practice trials until task could be consistently done in 2 to 5 seconds	0.000 3.89 1.77 85	0.033 3.88 1.99 85	0.090 5.37 3.23 85	0.107 4.72 2.96 85	0.080 4.25 2.10 85	0.059 4.67 2.38 85	0.044 3.69 1.70 85	0.159 P<0.01 (595)	50¢ per test trial could be earned if a score were under 110% of the control condition score (with no lower limit)
Social Female (6)		0.002 5.05 3.27 30	0.032 11.53 22.90 30	0.087 7.67 10.89 30	0.112 5.30 3.06 30	0.068 4.10 2.19 25	0.062 4.02 1.57 30	0.040 3.98 2.48 30	0.059 p >.05 (205)	
Registry Male (1)		0.000 7.00 1.73 5	0.020 5.70 0.45 5	0.085 4.20 0.84 5	0.115 8.20 2.86 5	0.145 6.00 1.22 5	0.110 5.20 1.30 5	0.100 5.20 0.84 5	-.053 p >.05 (35)	
Registry Female (1)		0.025 9.50 3.20 5	0.060 10.30 3.82 5	0.065 8.00 3.02 5	0.155 10.90 4.42 5	0.115 9.30 5.01 5	0.075 13.20 4.03 5	0.050 13.00 4.47 5	-0.22 p >.05 (35)	
Control Male Social (5)		---- 4.44 3.35 25	---- 3.34 1.53 25	---- 3.88 2.22 25	---- 3.30 0.98 25	---- 5.54 5.05 25	---- 4.32 4.18 25	---- 2.27 1.03 24	(--)	
Control Female Social (1)		---- 3.70 1.86 5	---- 3.10 2.19 5	---- 3.50 2.00 5	---- 2.40 0.42 5	---- 3.00 1.17 5	---- 2.00 0.00 5	---- 2.80 1.30 5	(--)	
Totals for Drinking (25)		0.007 4.52 2.58 125	0.036 6.05 11.71 125	0.082 5.98 6.03 125	0.122 5.25 3.29 125	0.102 4.50 2.47 120	0.077 4.88 2.33 125	0.059 4.19 2.72 125	0.156 p <0.005 (835)	

TABLE A-3 SUMMARY OF ANALYSIS OF VARIANCE FOR 17 MALE SOCIAL DRINKERS ON THE PROTOTYPE THEFT LOCK DEVICE

Sources of Variance	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio
Total	594	348,186.25	586.17	
Repetitions (5)	4	4,939.25	1,234.81	2.62*
Testing Conditions (7)	6	17,810.50	2,968.42	4.76**
Subjects (17)	16	49,699.50	3,106.20	
R x T	24	15,119.50	629.98	
R x S	64	30,144.00	471.00	
T x S	96	59,833.25	623.26	
R x T x S	384	170,640.50	444.38	

*p<0.05. **p<0.01.

TABLE A-4. SUMMARY OF ANALYSIS OF VARIANCE FOR SIX FEMALE SOCIAL DRINKING SUBJECTS USING THE PROTOTYPE THEFT LOCK DEVICE

Sources of variance	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio
Total	209	2,095,900.50	10,038.23	
Repetitions(5)	4	16,476.75	4,119.19	1.31
Testing Conditions(7)	6	137,428.00	22,904.66	1.04
Subjects(6)	5	196,173.12	39,234.62	1.04
RxT	24	127,271.25	5,302.97	
RxS	20	62,789.00	3,139.45	
TxS	30	663,348.50	22,111.61	
RxTxS	120	892,413.87	7,436.78	

Finally, Figure A-3 shows the scatterplot of the performance time (in seconds) on the Prototype Theft Lock Device for all drinking subjects as a function of BAQ ($r_T(N = 835) = 0.156$, $p<0.05$).

A-2.3.2 Critical Flicker-Fusion Tester

A-2.3.1 Description of Subject's Task on the Device - This unit, developed by Creare Incorporated[4], requires the operator to indicate whether the target light is flickering or steady. The device's ability to determine intoxication is dependent upon a reduction in the critical flicker-fusion frequency which accompanies intoxication. In reality, the target is always flickering, but the rate of flicker reaches a point at which the operator sees it as steady. In practice, the device must be set for each operator's normal flicker threshold. Then, if his judgment is incorrect on more than a preset number of trials, he is prevented from starting his vehicle.

A-2.3.2 Results - Subjects' thresholds were measured three times at each testing condition. Responses are measured in terms of the frequency at which the subject notices a change from a steady to a flickering target and the reverse. Table A-5 lists mean BAQ attained, mean critical flicker-fusion threshold (in Hz), standard deviation(assuming that the distribution was normal, which was not the case), and the number of data points per cell. The correlation coefficient of BAQ with performance is shown, along with the number of pairs and level of significance, for each group of subjects. Training criteria and motivation scheme are also listed.

Figure A-4 shows the mean critical flicker-fusion frequency for the eight female social drinking subjects and the one female social control subject as a function of testing conditions. Figure A-5 shows the same for the 17 male social drinking subjects and the one male social control subject.

A summary of an analysis of variance for the male social drinking subjects is reported in Table A-6. This analysis showed that only the testing-conditions variable [$F(6,102)=5.36, p<0.005$] reached significance. A Tukey WSD test showed after analysis of

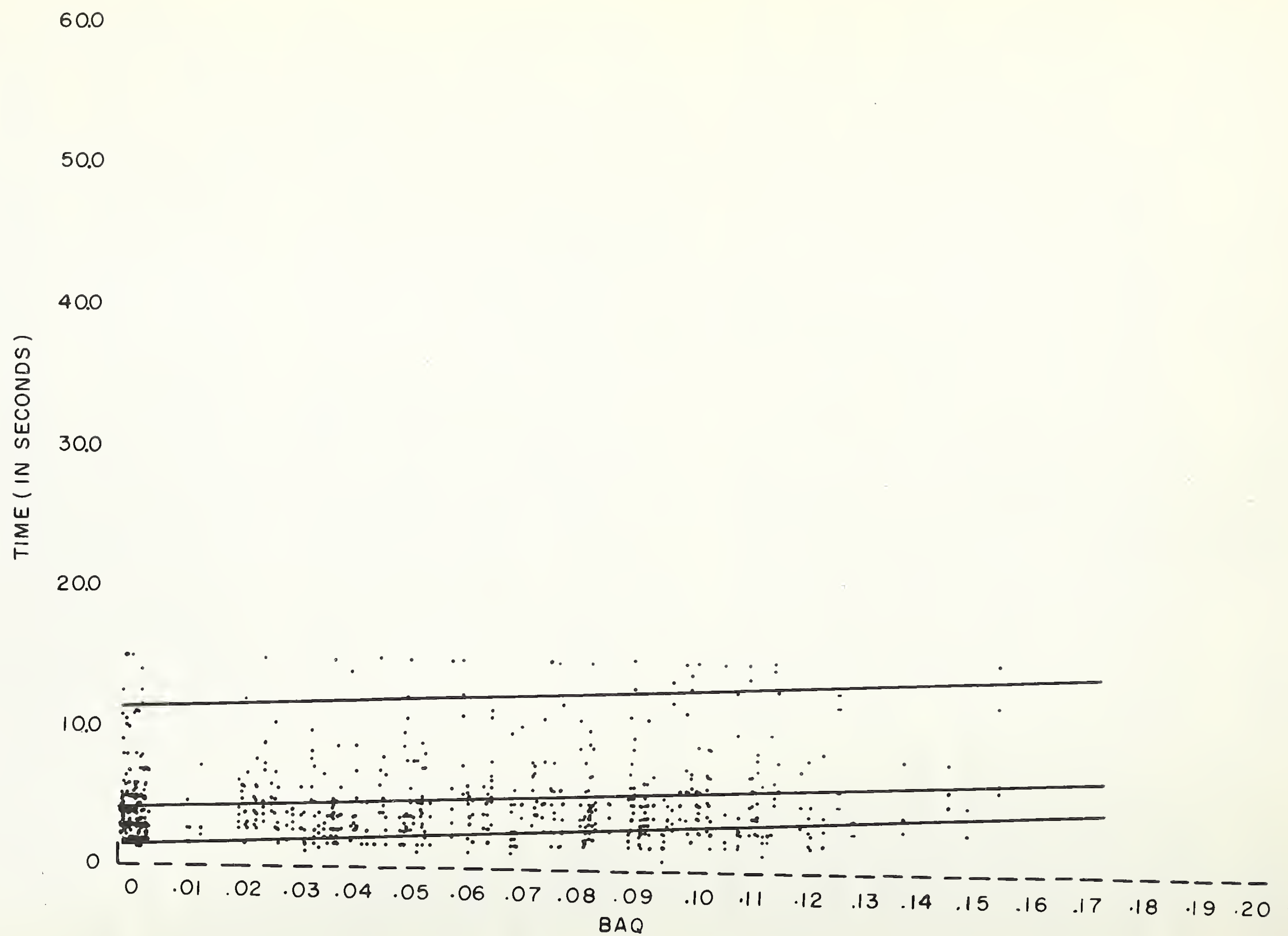

Figure A-3. Scatterplot of Performance Time (in Seconds) on the Prototype Theft Lock Device as a Function of BAQ, and Regression Line with Brackets Enclosing 80% of the Points

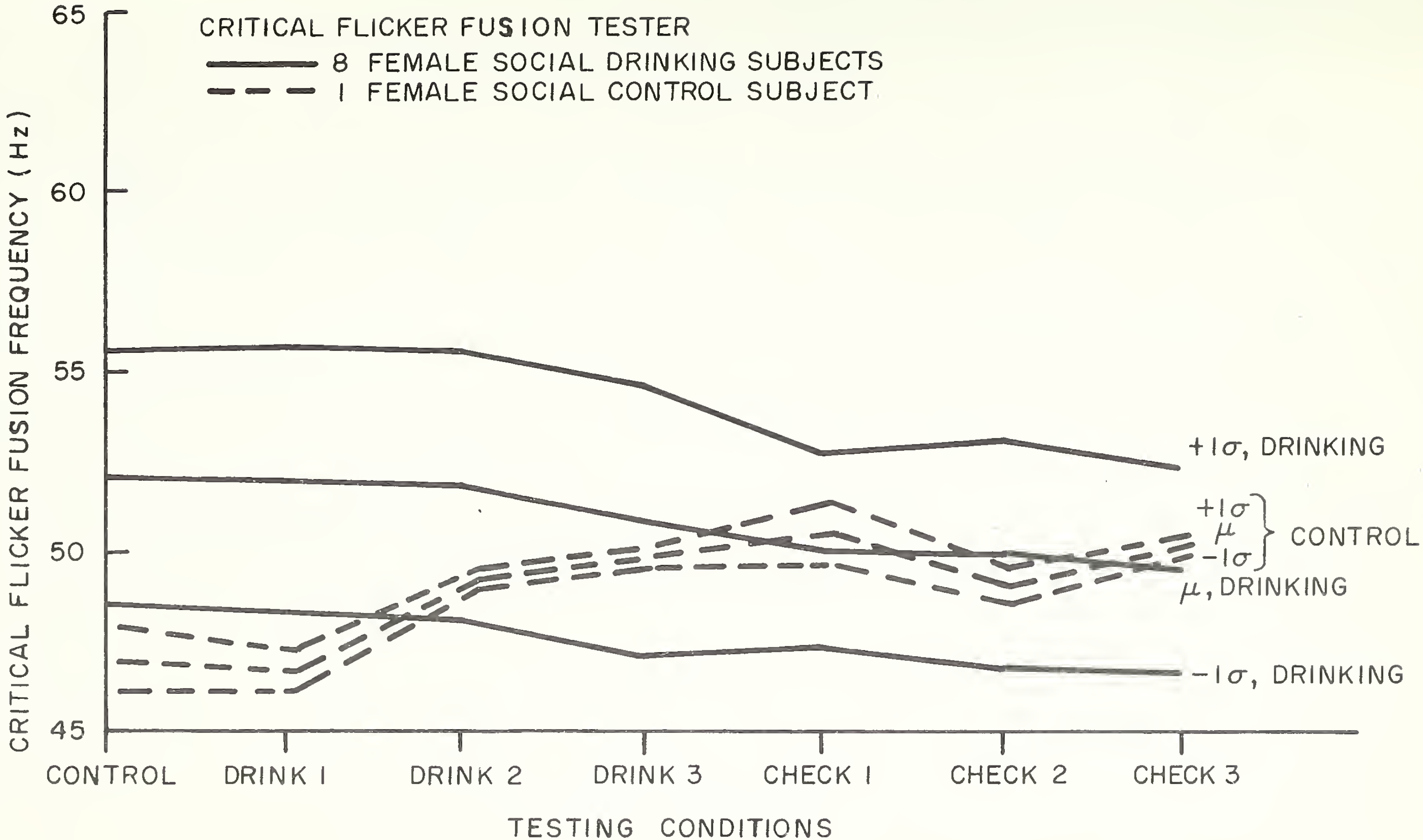

Figure A-4. Performance on the Critical Flicker Fusion Tester as a Function of Testing Conditions for Eight Female Social Drinking Subjects and One Female Control Subject

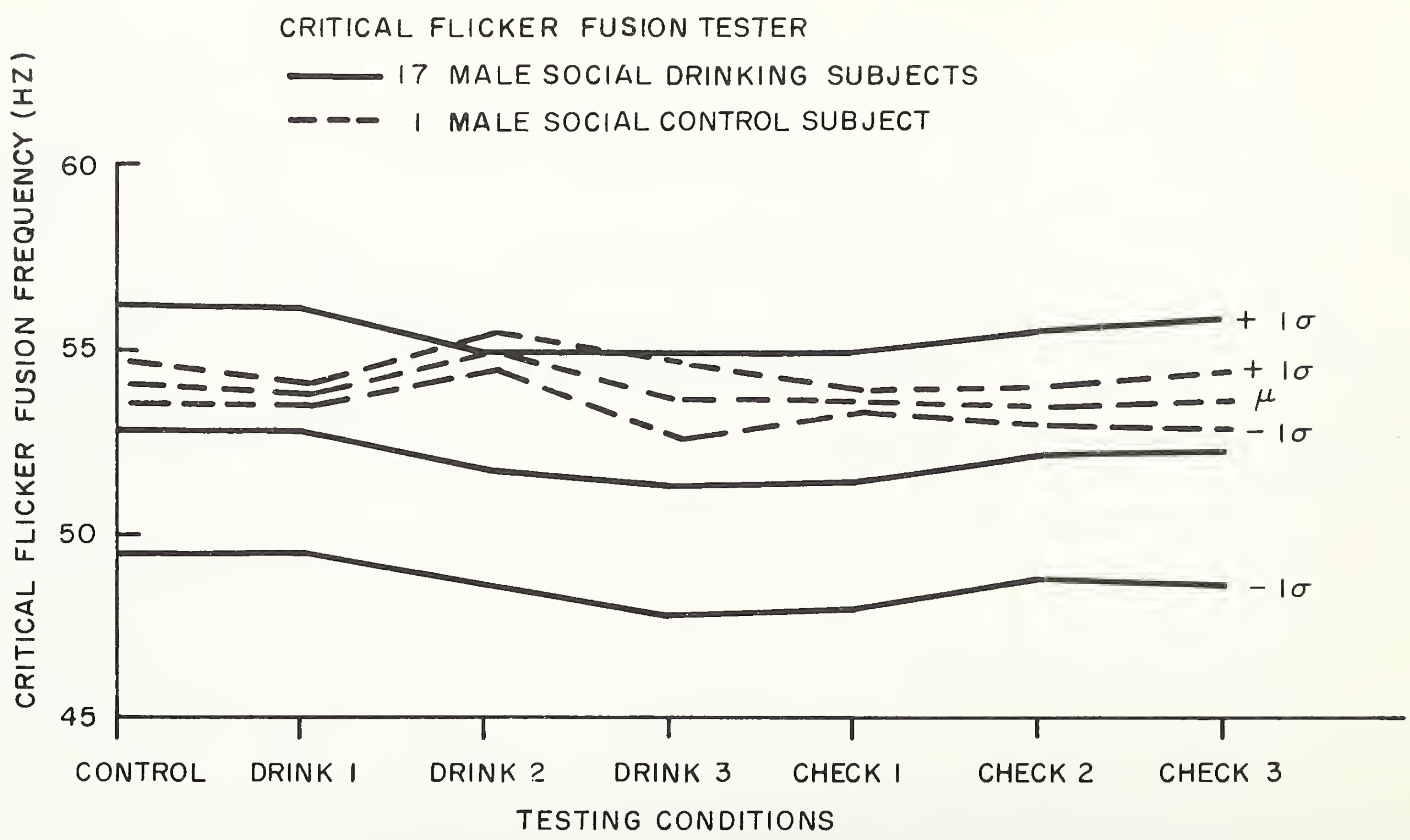

Figure A-5. Performance on the Critical Flicker Fusion Tester as a Function of Testing Conditions for 17 Male Social Drinking Subjects and One Male Social Control Subject

TABLE A-5. SUMMARY OF PERFORMANCE ON THE CRITICAL FLICKER FUSION DEVICE

CREARE INC.	DAY 1	DAY 2 - TESTING PERFORMANCE MEASURED AS THRESHOLD FREQUENCY (IN Hz) Subjects performed three threshold trials within each testing condition)								
Type + No. of Subjects	Training	Control	Drink 1	Drink 2	Drink 3	Check 1	Check 2	Check 3	Correlation of BAQ and Performance + No. of Subjects	Motivation (Bonus Money)
Social Male (17)	Five thresholds were obtained for flicker and five thresholds for shady light.	0.001 52.83 3.40 51	0.034 52.79 3.33 51	0.087 51.76 3.15 51	0.103 51.30 3.53 51	0.077 51.40 3.48 45	0.055 52.10 3.35 42	0.042 52.23 3.58 45	-0.257 P<0.01 (336)	50¢ per test trial could be earned if a score were ±3 Hz of the control score.
Social Female (3)		0.000 52.10 3.52 24	0.029 52.00 3.69 24	0.079 51.85 3.74 24	0.108 50.86 3.78 24	0.078 50.06 2.70 18	0.057 49.97 3.16 18	0.036 49.50 2.85 15	0.02 p>0.05 (147)	
Registry Male (2)		0.000 53.08 1.46 6	0.033 54.68 1.05 6	0.095 52.93 0.656 6	0.133 54.00 0.548 6	0.100 53.93 0.575 6	0.090 54.68 1.33 6	0.068 54.10 0.533 6	0.085 p>0.05 (42)	
Registry Female (1)		0.025 52.00 0.500 3	0.060 51.83 0.289 3	0.065 51.50 0.000 3	0.155 49.83 0.289 3	0.115 50.17 0.289 3	0.075 51.33 0.089 3	0.050 52.17 0.577 3	-0.905 P<0.01 (21)	
Control Male Social (1)		0.000 54.17 0.577 3	0.000 53.82 0.289 3	0.000 55.00 0.500 3	0.000 53.67 1.04 3	0.000 53.67 0.289 3	0.000 53.50 0.500 3	0.000 53.67 0.764 3	(--)	
Control Female Social (1)		0.000 47.00 0.866 3	0.000 46.67 0.577 3	0.000 49.17 0.289 3	0.000 49.83 0.289 3	0.000 50.50 0.866 3	0.000 49.00 0.500 3	0.000 50.17 0.289 3	(--)	
Totals for Drinking (28)									-0.107 P<0.05 (567)	

TABLE A-6. SUMMARY OF ANALYSIS OF VARIANCE FOR 17 MALE SOCIAL DRINKING SUBJECTS ON THE CRITICAL FLICKER-FUSION DEVICE*

Sources of Variance	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio
Total	377	409,952.0	1,087.41	
Repetitions (3)	2	80.0	40.0	1.25
Testing (7) Conditions	6	10,720.0	1,786.67	5.36**
Subjects (18)	17	355,424.0	20,907.29	
R x T	12	448.0	37.33	
R x S	34	1,088.0	32.02	
T x S	102	33,792.0	333.29	
R x T x S	204	8,400.0	41.18	

*Due to an error, one male registry subject was counted as a male social subject; however, correcting for this error would not alter the results of this analysis.
**p < 0.005

TABLE A-7. SUMMARY OF ANALYSIS OF VARIANCE FOR EIGHT FEMALE SOCIAL DRINKING SUBJECTS ON THE CRITICAL FLICKER-FUSION DEVICE

Sources of Variance	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio
Total	167	179,352.0	1,073.96	
Repetitions (3)	2	152.0	76.0	1.30
Testing Conditions (7)	6	13,952.0	2,352.33	35.59*
Subjects (18)	7	165,112.0	23,587.43	
R x T	12	464.0	38.67	
R x S	14	816.0	58.29	
T x S	42	2,776.0	66.10	
R x T x S	84	1,632.0	19.43	

*p. < 0.01

variance that the means of the control and the drink-1 conditions were significantly different from the means of the drink-2, drink-3 and check-1 testing conditions. All other means were not significantly different from each other.

An analysis of variance for the eight female social subjects again showed only testing conditions [$F(6,42)=35.59$, $p<0.01$] to be significant. A summary of this analysis is presented in Table A-7.

Finally, Figure A-6 shows the scatterplot of the critical flicker-fusion frequency (Hz) for all drinking subjects as a function of BAQ (r_T ($N=567$) = -0.11, $p<0.05$).

A-2.3.3 Drunk-Driver Eliminator

A-2.3.3.1 Description of Subjects' Task on the Device - This unit, developed by the TDL Group of Companies[5], requires the operator to make closely coordinated and sequenced manual and pedal responses. Specifically, the operator turns a key and immediately depresses the brake pedal. Responses having a long latency, and/or the inversion of the standard manual/pedal response sequence are considered to indicate intoxication, and result in the operator's failing the test. Response time in measured in milliseconds from the turning of the key to the depression of the brake pedal.

A-2.3.3.2 Results - Subjects repeated the task 15 times for each of the seven testing conditions. Table A-8 gives mean BAQ attained, mean time to complete the task, standard deviation (assuming that the distribution was normal, which was not the case), and the number of data points per cell. The correlation coefficients of BAQ with performance are shown, along with the number of pairs and level of significance, for each group of drinking subjects. Training criterion and motivation schemes are also listed.

Figure A-7 shows the mean reaction time in milliseconds for the 16 male social drinking subjects and the five male social control subjects as a function of testing conditions. Means

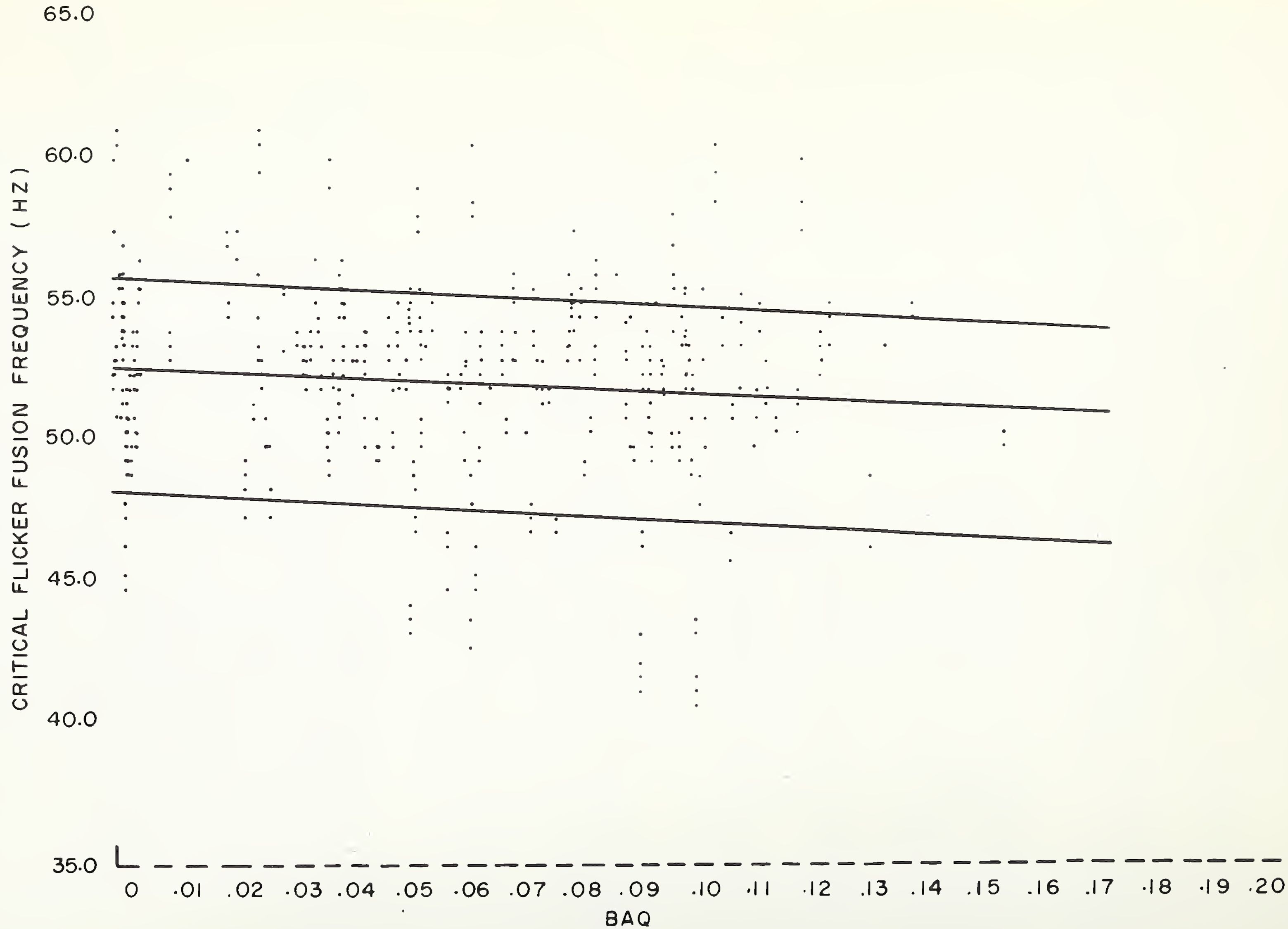

Figure A-6. Scatterplot of Critical Flicker Fusion Frequency (Hz) as a Function of BAQ for all Drinking Subjects, and Regression Line with Brackets enclosing 80% of the Points

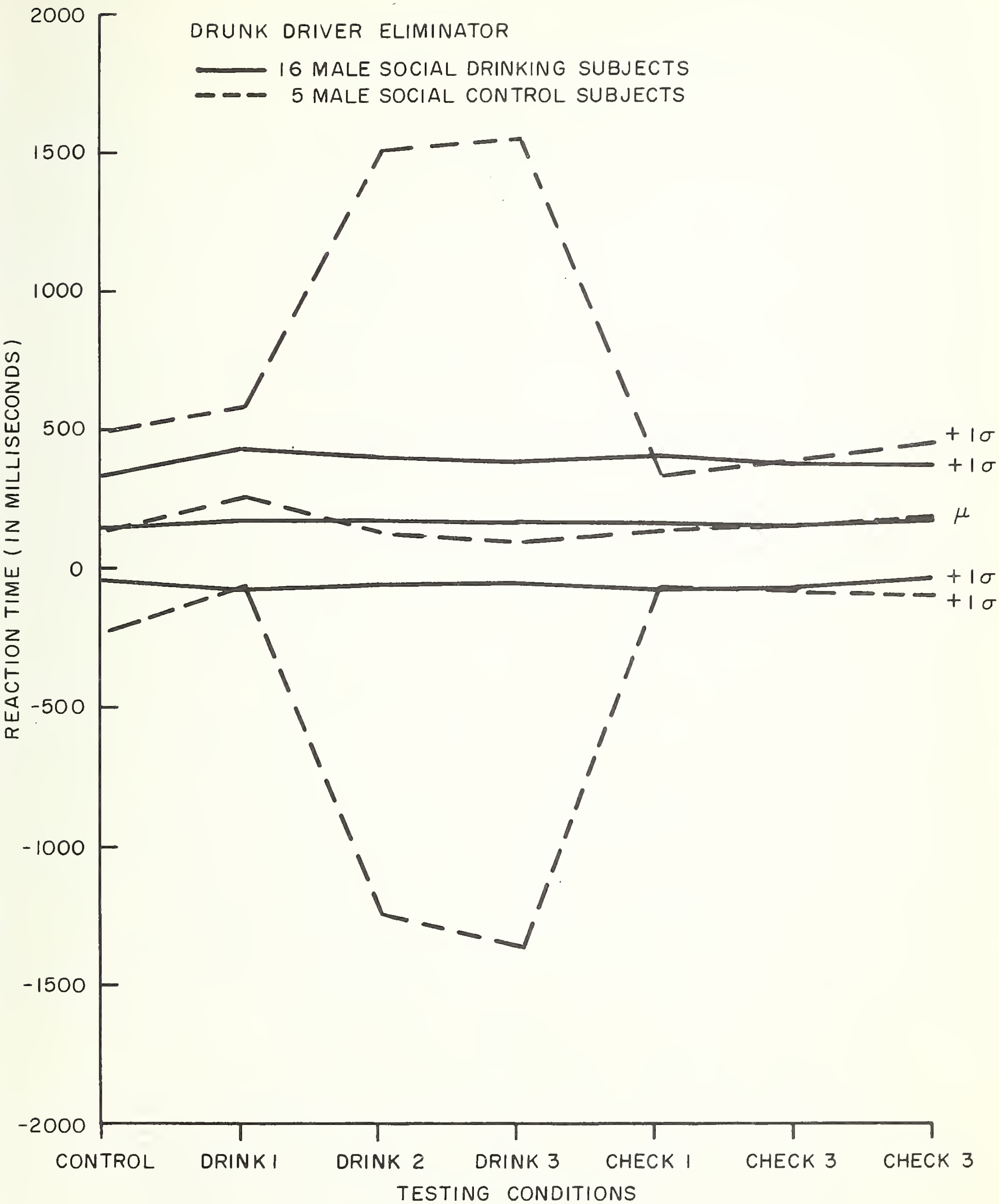

Figure A-7. Performance on the Drunk-Driver Eliminator as a Function of Testing Conditions for the 16 Male Social Drinking and the Five Male Social Control Subjects

TABLE A-8. SUMMARY OF PERFORMANCE ON THE DRUNK-DRIVER ELIMINATOR DEVICE

TDL	DAY 1	DAY 2 - TESTING PERFORMANCE AS REACTION TIME (IN MILLISECONDS) Subjects performed 15 repetitions within each testing condition)								
Type + No. of Subjects	Training	Control	Drink 1	Drink 2	Drink 3	Check 1	Check 2	Check 3	Correlation BAQ X Perf.	Motivation (Bonus Money)
Social Male (16)	Between 20 and 30 trials were run for each Subject.	0.000 141.16 182.90 227	0.032 173.91 252.94 202	0.088 169.47 281.11 208	0.103 163.77 220.14 207	0.075 164.56 242.72 223	0.051 151.11 224.29 212	0.035 170.94 203.78 206	0.075 P<0.05 (1485)	No bonus money was paid on this task.
Social Female (6)		0.002 141.53 1136.10 81	0.032 14.27 163.90 71	0.087 124.05 223.07 76	0.113 152.35 224.35 64	0.082 127.31 192.06 64	0.060 136.05 1866.36 77	0.040 140.16 193.10 77	0.03 p > 0.05 (520)	
Registry Male (2)		0.00 320.17 310.02 30	0.034 152.28 233.82 25	0.088 184.75 277.70 24	0.138 234.85 286.86 20	0.110 160.91 235.23 23	0.098 101.91 245.29 22	0.078 76.65 109.56 20	-0.106 p> 0.05 (164)	
Registry Female (1)		0.025 186.20 89.37 10	0.060 242.29 154.42 14	0.065 164.64 62.08 11	0.155 112.64 73.94 11	0.115 85.60 74.28 15	0.075 84.82 48.32 11	0.050 87.64 61.54 14	-0.243 p > 0.05 (86)	
Control Male Social (5)		---- 125.16 359.21 55	---- 252.53 321.00 51	---- 120.54 1374.76 57	---- 85.41 1457.36 51	---- 129.05 195.40 56	---- 147.09 233.08 56	---- 175.39 279.45 56	(--)	
Control Female Social (1)		---- 157.07 286.61 15	---- 168.46 256.49 13	---- 54.92 33.02 13	---- 137.00 258.93 14	---- 99.31 205.77 13	---- 178.00 273.05 10	---- 240.67 287.52 12	(--)	
Total for Drinking Subjects (25)		0.001 157.97 574.58 348	0.033 138.92 239.69 312	0.087 159.63 263.23 319	0.109 164.19 222.57 302	0.078 153.66 228.44 335	0.057 141.88 928.48 322	0.040 153.84 193.89 317	0.046 p >0.05 (2523)	

for the six female social drinking subjects and the one female social control subject are presented in Figure A-8.

A summary of the analysis of variance for the male social drinking subjects is reported in Table A-9. This analysis revealed that neither testing conditions nor repetitions reached significance. Similiar results were observed for the female social drinking subjects (Table A-10). The scatterplot of the reaction times (in milliseconds) as a function of BAQ for all subjects is given in Figure A-9 ($r_T(2523) = 0.046$, $p>0.05$.).

A-2.3.4 Pursuit-Tracking Tester with Secondary Detection Task

A-2.3.4.1 Description of Subjects' Task of the Device - Developed by the Transportation Systems Center, this device requires the operator to perform a pursuit-tracking task and simultaneously respond promptly and correctly to a pair of visual stimuli. In short, it is a divided-attention task, in which two different responses are required of a subject. Specifically, the operator tracks a moving target in a typical pursuit-tracking situation. The dependent variable is the integrated absolute position difference between the target and the operator-controlled indicator. At the same time, the operator is also required to monitor a separate display, pressing one of two response buttons depending on the picture presented. Here, the dependent variable is the per cent of correct responses to the visual stimulus. In practice, if the operator's tracking score exceeds a preset threshold, or if he responds too slowly or incorrectly to the visual stimuli, it is taken as an indication of intoxication.

A-2.3.4.2 Results - Subjects completed five trials for each of the seven testing conditions. Table A-11 gives mean BAQ attained, mean absolute difference error (in volt-seconds), standard deviation, and the number of data points per cell. The

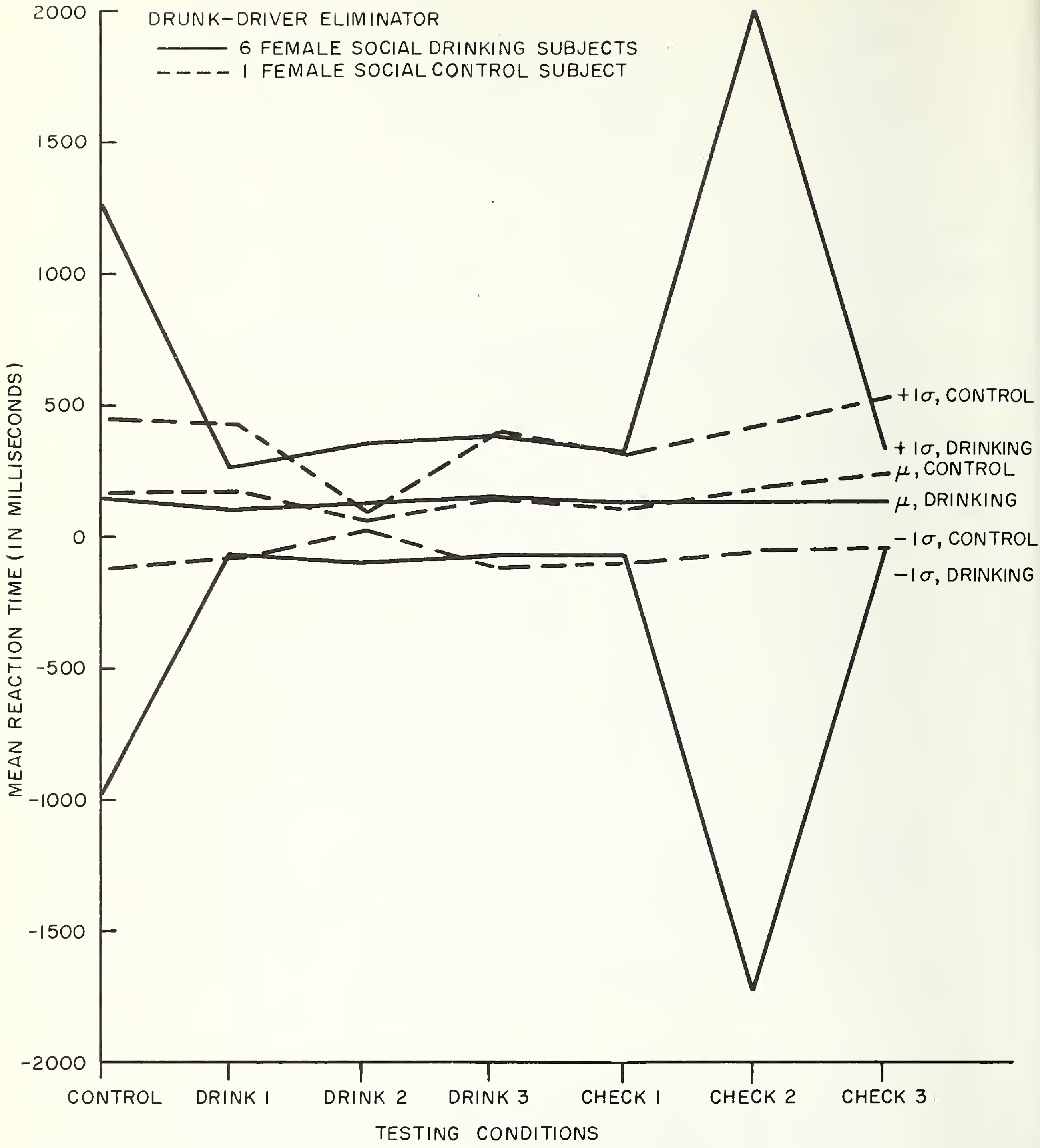

Figure A-8. Performance on the Drunk-Driver Eliminator as a Function of Testing Conditions for the Six Female Social Drinking and the One Female Social Control Subjects

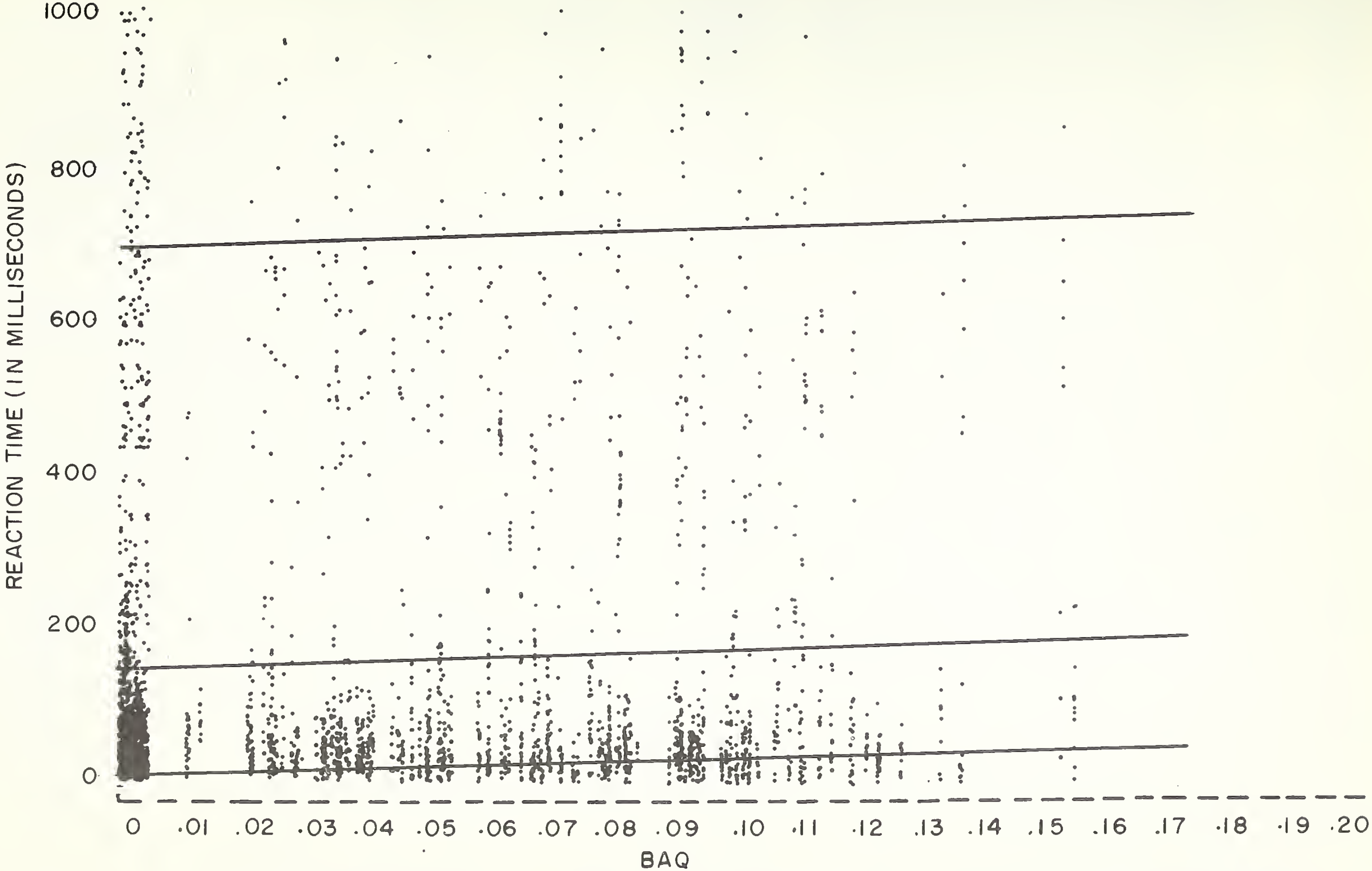

Figure A-9. Scatterplot of Reaction Time (in milliseconds) on the Drunk-Driver Eliminator as a Function of BAQ for All Drinking Subjects, and regression Line with Brackets Enclosing 80% of the Points

TABLE A-9. SUMMARY OF ANALYSIS OF VARIANCE FOR 16 MALE SOCIAL DRINKING SUBJECTS ON THE DRUNK-DRIVER ELIMINATOR*

Sources of Variance	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio
Total	1994	384,802,816.0	192,980.28	
Repetitions (3)	14	2,045,984.0	146,141.69	1.05**
Testing Conditions (7)	6	2,690,640.0	448,439.94	0.63**
Subjects (7)	17	26,581,856.0	1,476,769.50	
R x T	84	12,492,976.0	148,725.88	
R x S	252	35,037,776.0	139,038.78	
T x S	108	76,337,504.0	706,828.50	
R x T x S	1512	229,616,032.0	151,862.41	

*Due to an error, two male registry subjects were erroneously counted as male social drinking subjects. However, correcting for this error would not alter the results of this analysis.

**$p < 0.05$

TABLE A-10. SUMMARY OF ANALYSIS OF VARIANCE FOR SIX FEMALE SOCIAL DRINKING SUBJECTS ON THE DRUNK-DRIVER ELIMINATOR DEVICE

Sources of Variance	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio
Total	629	396,942,080.0	631,068.38	
Repetitions (15)	14	5,980,032.0	427,145.06	1.05*
Testing Conditions (7)	6	14,516,836.0	2,419,472.50	1.07*
Subjects (6)	5	22,495,708.0	4,499,141.00	
R x T	84	38,441,136.0	457,632.50	
R x S	70	28,559,636.0	407,994.75	
T x S	30	68,176,864.0	2,272,561.50	
R x T x S	420	218,771,744.0	520,885.06	

* $p. < 0.05$

TABLE A-11. SUMMARY OF PERFORMANCE ON THE PURSUIT TRACKING TESTER WITH RECORDING DETECTION TASK

DOT-TSC	DAY 1	DAY 2	DAY 3 - TESTING PERFORMANCE IN ABSOLUTE DIFFERENCE ERROR (IN VOLT-SECONDS) (Subjects performed 5 repetitions within each testing condition)								
Type + No. of Subjects	Training	Training	Control	Drink 1	Drink 2	Drink 3	Check 1	Check 2	Check 3	Correlation BAQ X Perf.	Motivation (Bonus Money)
Social Male (15)	Subjects were run for four sessions with 10 trials per session Total-40 trials	Subjects were run for four sessions with 10 trials per session Total-40 trials	0.001 212.36 45.99 75	0.032 204.61 63.78 75	0.077 226.20 76.43 75	0.103 270.71 104.02 75	0.080 231,64 73.32 75	0.061 221.83 70.18 75	0.042 205.53 65.46 75	0.214 P<0.01 (525)	50¢ per test trial could be earned if a score was not over 110% of the control score (with no lower limit).
Social Female (5)			0.000 199.12 21.95 25	0.036 210.48 53.30 25	0.083 251.80 58.16 25	0.116 295.76 78.46 25	0.088 249.24 56.50 25	0.062 230.32 41.14 25	0.043 217.36 44.60 25	0.545 P<0.01 (175)	
Registry Male (11)			0.014 266.16 82.89 55	0.040 251.73 72.25 55	0.081 266.73 82.14 55	0.144 411.47 168.15 55	0.109 323.91 115.05 55	0.090 281.87 88.16 55	0.073 262.15 79.63 55	0.393 P<0.01 (385)	
Registry Female (2)			0.023 332.80 90.97 10	0.030 308.30 112.13 10	0.078 331.90 135.69 10	0.125 564.50 185.43 10	0.095 378.80 431.36 5	0.065 348.80 395.34 5	0.040 310.20 348.60 5	0.594 P<0.01 (55)	
Control Male Social (0)											
Control Female Social (0)											
Total for Drinking Ss (33)			0.007 235.59 71.28 165	0.035 227.49 74.42 165	0.079 249.99 84.41 165	0.120 339.18 155.77 165	0.092 270.71 119.58 160	0.071 247.76 101.03 160	0.053 230.11 91.50 160	0.392 P<0.025 (1140)	

correlation coefficients of BAQ with performance are shown, along with the number of pairs and level of significance, for each group of drinking subjects. Training procedure and motivation scheme used are also listed.

Figure A-10 shows the mean integrated-absolute-difference error (in volt-seconds) for the 15 male social drinking subjects as a function of testing conditions. There were no male social control subjects for this test. Figure A-11 gives the mean error for the five female social drinking subjects. Again, there were no female social control subjects. Instead, a realistic number of registry subjects were run. Figure A-12 shows the mean integrated-absolute-difference error in volt-seconds for the 11 male registry drinking subjects as a function of testing conditions. Means for the two female registry drinking subjects are given in Figure A-13.

Because there were no control subjects and relatively few female subjects, it was decided to pool the registry and social subjects, ignoring gender differences, and analyze the data for differences due to drinking history. Figure A-14 shows the mean integrated-absolute-difference error (in volt-seconds) as a function of testing conditions for the 20 social and 12* registry subjects. Figure A-15 shows the percentage of correct responses to the visual stimuli for the same groups of subjects.

A summary of the analysis of variance for the mean integrated-absolute-difference error for the 20 social subjects is reported in Table A-12. Both repetitions ($F(4,76)=4.46$, $p<0.01$) and testing conditions ($F(6,114)=11.33$, $p<0.001$) reached significance. A Tukey WSD test showed that performance in the drink-3 condition was significantly poorer than that in all other testing conditions. No other significant mean differences were found.

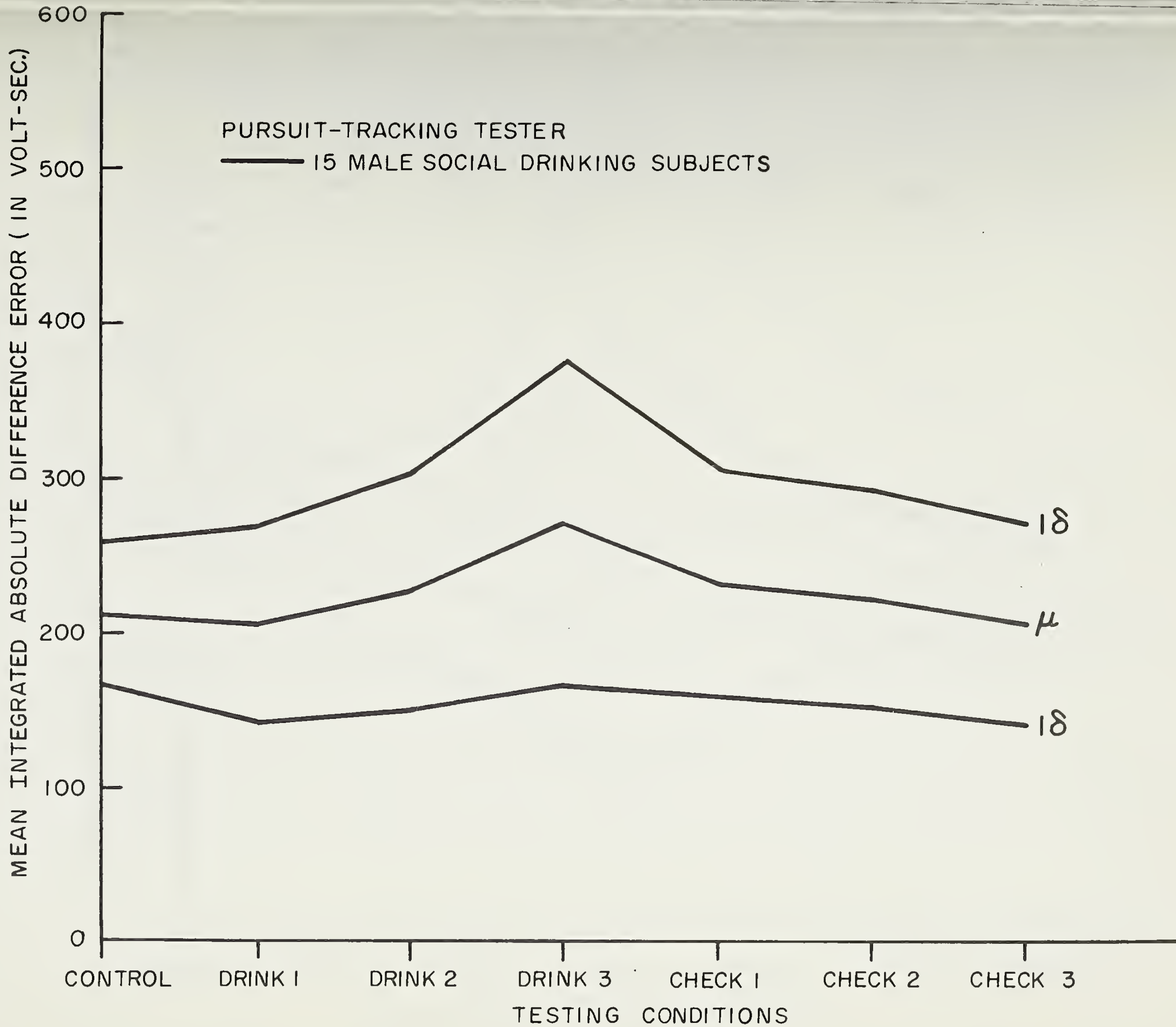

Figure A-10. Performance on the Pursuit-Tracking Tester as A Function of Testing Conditions for the 15 Male Social Drinking Subjects

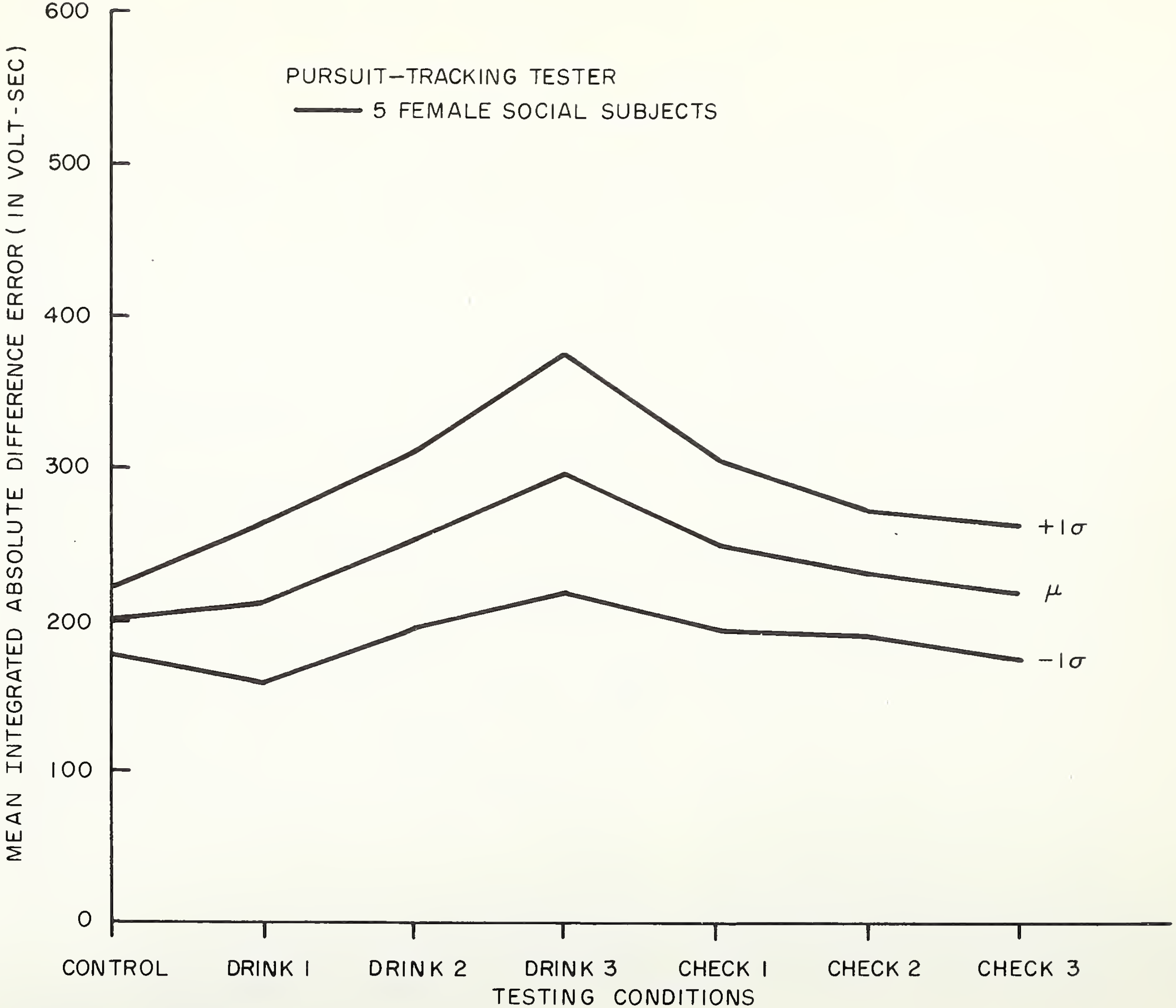

Figure A-11. Performance on the Pursuit-Tracking Tester as a Function of Testing Conditions for the Five Female Social Drinking Subjects

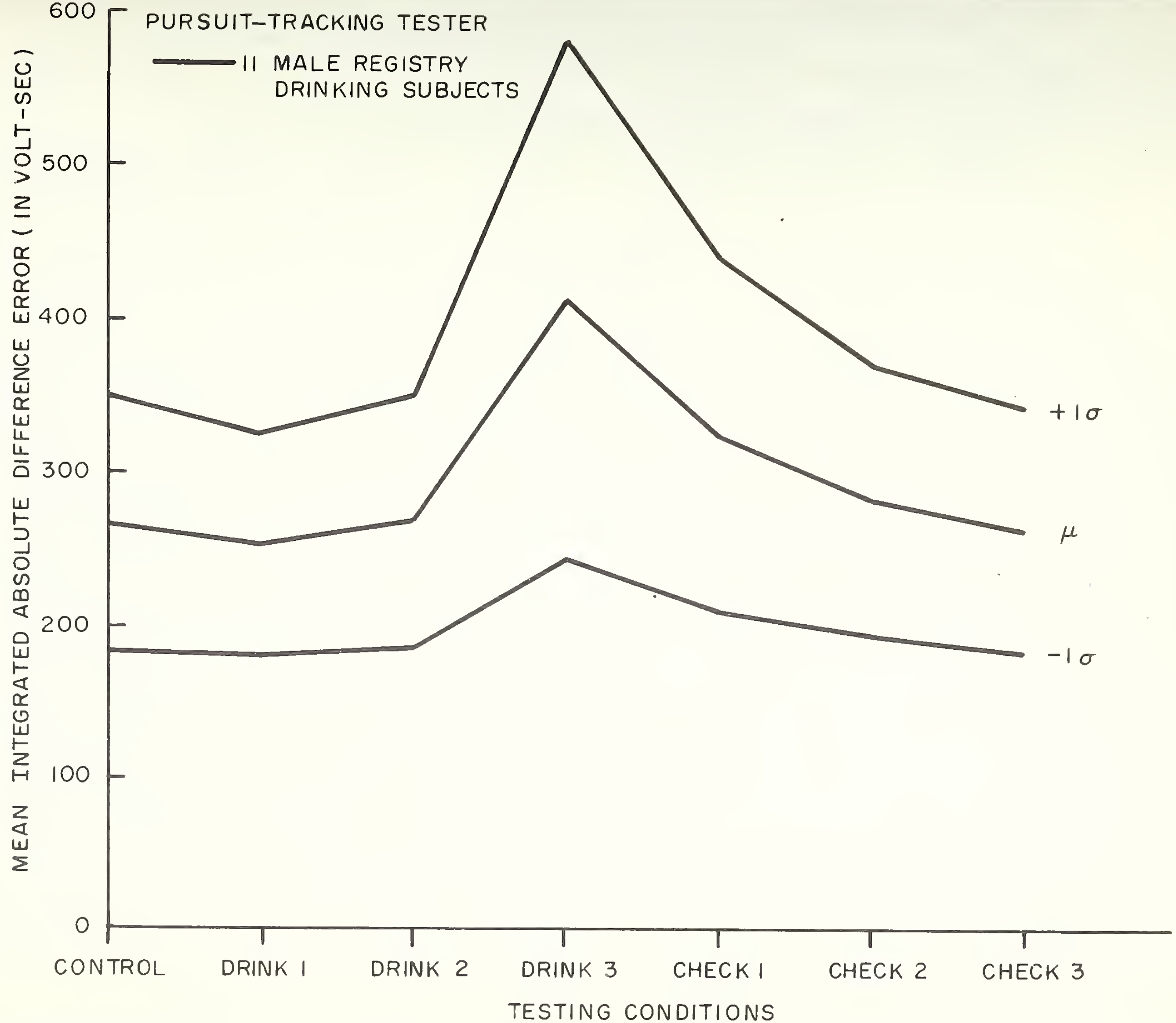

Figure A-12. Performance on the Pursuit-Tracking Tester as a Function of Testing Conditions for the 11 Male Registry Drinking Subjects

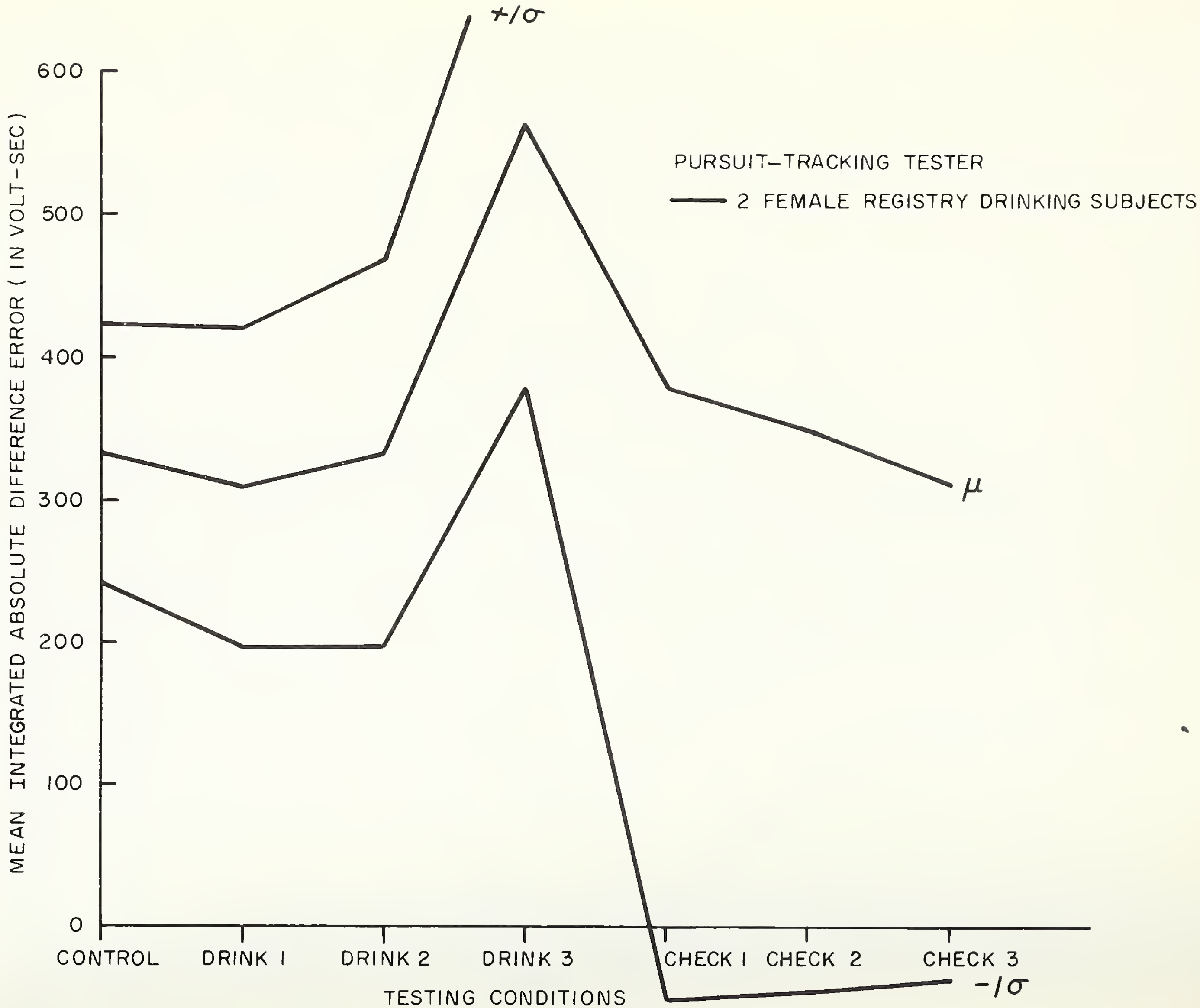

Figure A-13. Performance on the Pursuit-Tracking Tester as a Function of Testing Conditions for the Two Female Registry Drinking Subjects

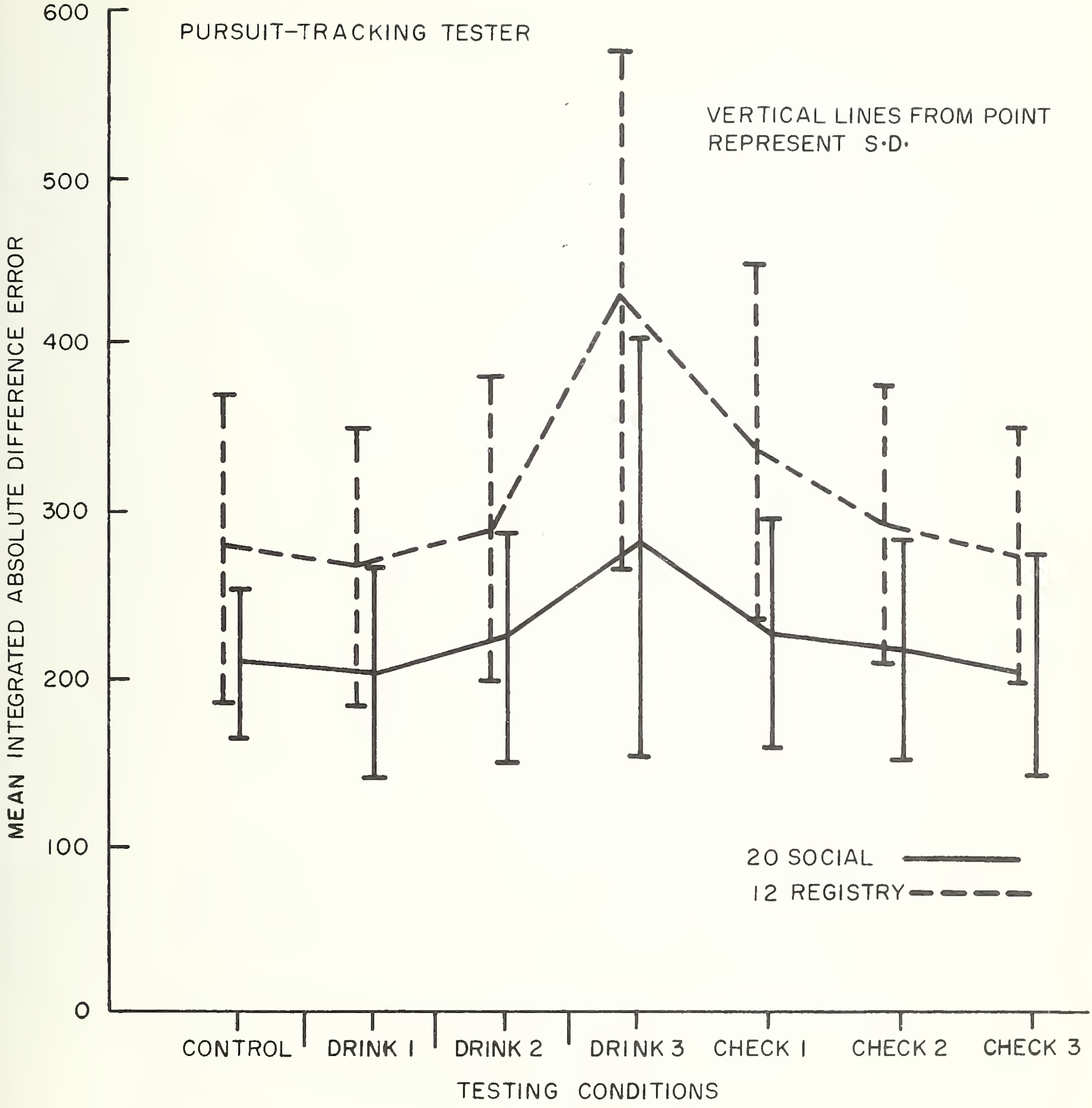

Figure A-14. Performance on the Pursuit-Tracking Tester as a Function of Testing Conditions for the 20 Social and 12* Registry Drinking Subjects

*Note: One subject was dropped from this graph because she became ill and did not complete the series.

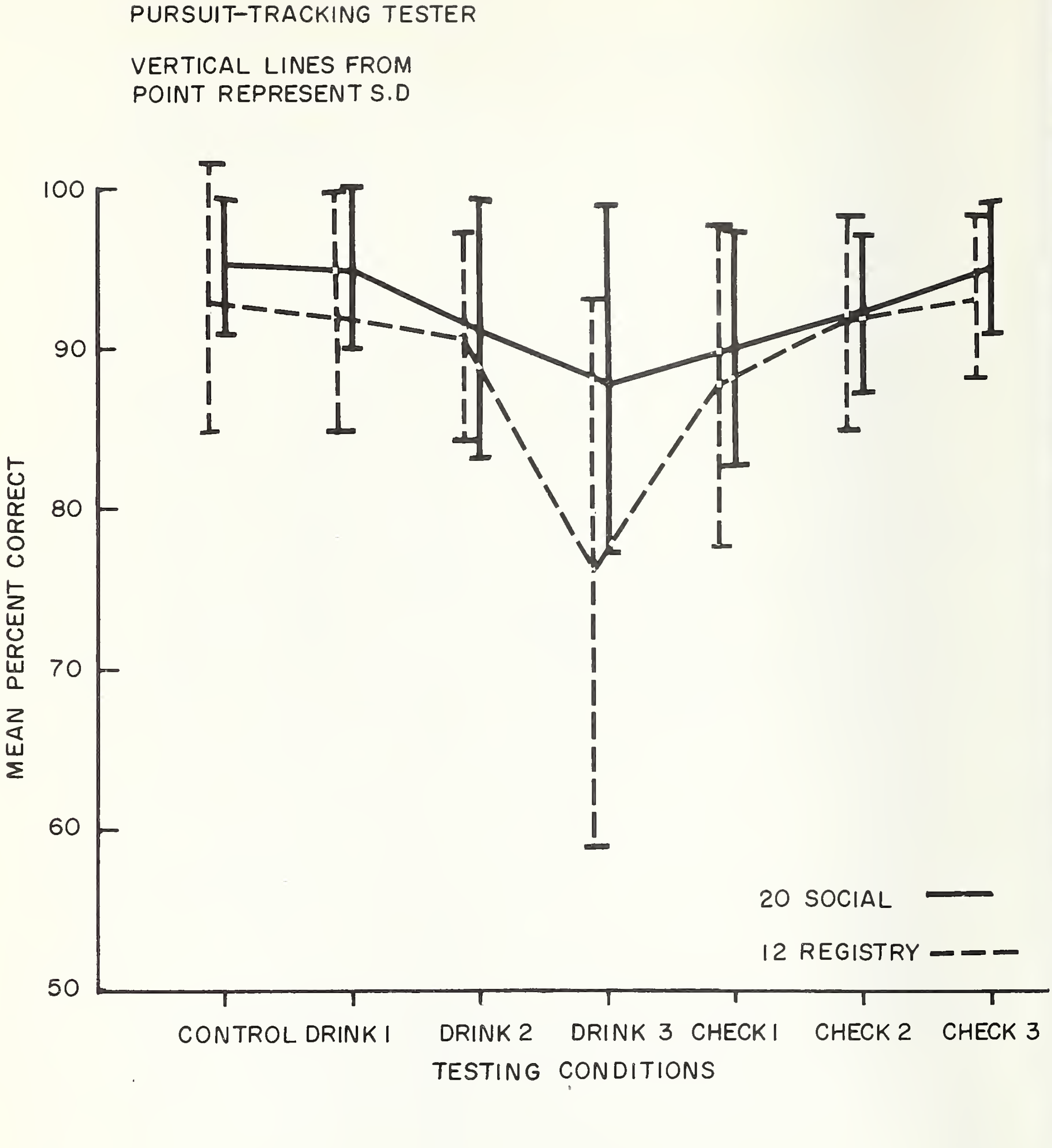

Figure A-15. Performance on the Pursuit-Tracking Tester (in percentage of correct responses) as a Function of Testing Conditions for the 20 Social and 12* Registry Drinking Subjects

*Note: One subject was dropped from this graph because she became ill and could not complete the series.

TABLE A-12. SUMMARY OF ANALYSIS OF VARIANCE FOR THE 20 SOCIAL DRINKING SUBJECTS ON THE PURSUIT-TRACKING TESTER: INTEGRATED-ABSOLUTE-DIFFERENCE ERROR DATA

Sources of Variance	Degrees of Freedom	Sum of Squares	Mean Squares	F Ratio
Total	699	4,212,416.0	6,026.35	
Repetitions (5)	4	27,872.0	6,968.00	4.46*
Test. Cond's(7)	6	439,632.0	73,271.98	11.33**
Subjects (20)	19	2,344,264.0	123,382.30	
R x T	24	29,952.0	1,248.00	
R x S	76	118,792.0	1,563.05	
T x S	114	737,320.0	6,467.72	
R x T x S	456	514,584.0	1,128.47	

*$p < 0.01$

**$p < 0.001$

A summary of the analysis of variance for the integrated-absolute-difference error for 12* registry subjects is reported in Table A-13. Only the testing condition ($F(6,66)=16.51$, $p <0.001$), not the repetitions within each trial ($F(4,44)=0.68$, $p <0.05$), was statistically significant. Again, the Tukey WSD test showed that performance in the drink-3 condition was significantly poorer than in all other testing conditions. No other significant mean differences were found.

*One subject was dropped from the analysis because she became ill and did not complete the series.

TABLE A-13. SUMMARY OF ANALYSIS OF VARIANCE FOR 12* REGISTRY SUBJECTS ON THE PURSUIT-TRACKING TESTER: INTEGRATED-ABSOLUTE-DIFFERENCE ERROR DATA

Sources of Variance	Degrees of Freedom	Sum of Squares	Mean Squares	F Ratio
Total	419	5,384,736.0	12,851.40	
Repetitions (5)	4	12,664.0	3,166.00	0.68
Test. Cond's(7)	6	1,171,048.0	195,174.62	16.51**
Subjects (12)	11	2,105,160.0	191,378.12	
R x T	24	64,280.0	2,678.33	
R x S	44	204,744.0	4,653.27	
T x S	66	780,352.0	11,823.51	
R x T x S	264	1,046,488.0	3,963.97	

*One subject was dropped from the analysis because she became ill and did not complete the series.

**$p < 0.001$

A summary of the analysis of variance for the social drinking subjects' correct responses to visual stimuli is reported in Table A-14. This analysis showed testing conditions ($F(6,114)= 6.55$, $p < 0.01$) to be a significant effect. A Tukey WSD test showed that performance in the drink-3 condition was significantly poorer than on any other trial. No other significant differences were found.

A summary of the analysis of variance on the percentage of correct data for the registry drinking subjects is presented in Table A-15. This analysis showed testing conditions ($F(6,66)= 9.28$, $p < 0.01$) to be significant. A Tukey WSD test showed that here, too, performance in the drink-3 condition was significantly poorer than on any other trial, with no other significant mean differences.

Figure A-16 shows the scatterplot of the integrated-absolute-difference error for all subjects as a function of BAQ (r_T (N=1140) 0.392, $p < 0.001$).

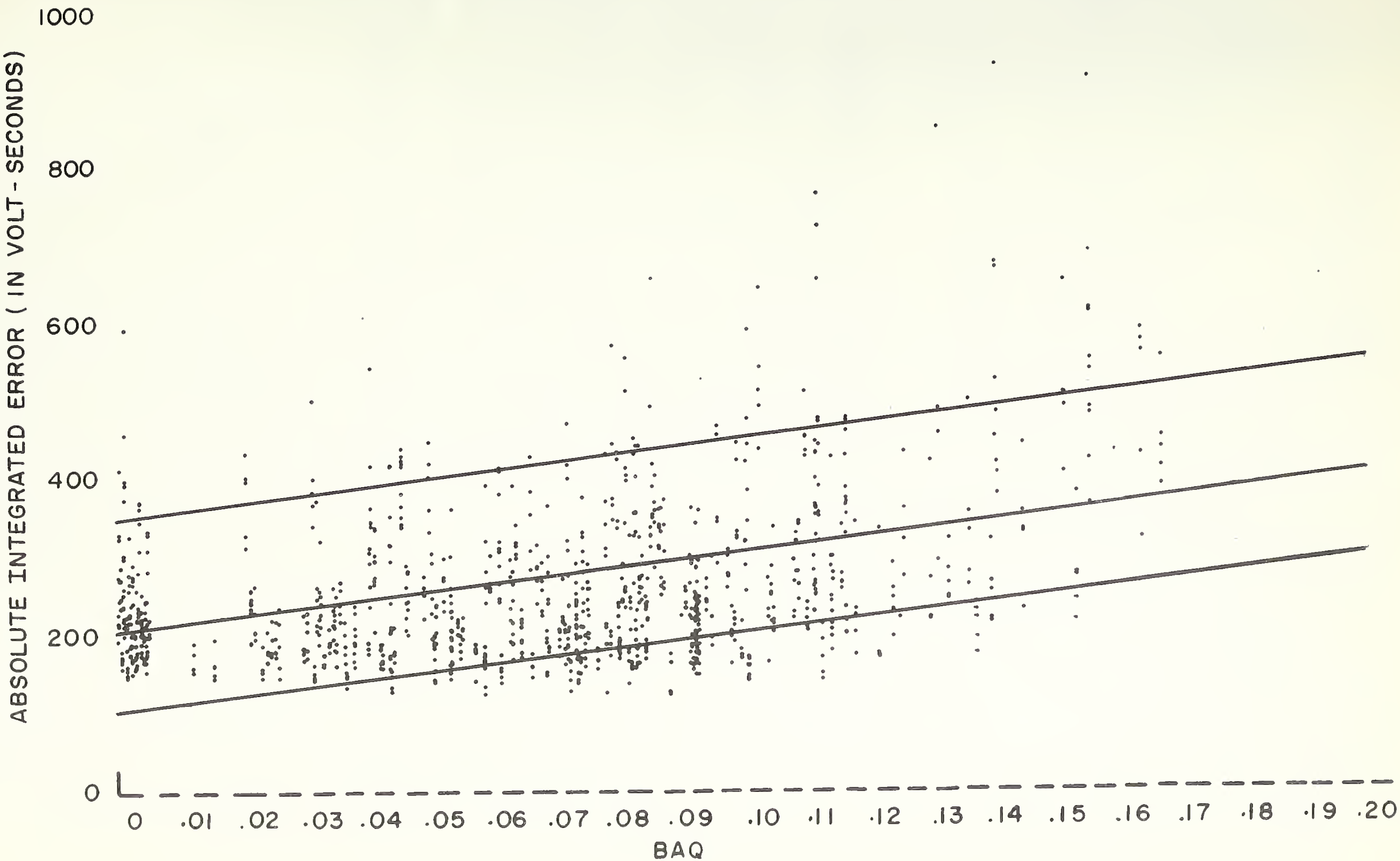

Figure A-16. Scatterplot of the Absolute Integrated Error (in volt-seconds) on the Pursuit-Tracking Tester with Secondary Detection Task Against BAQ for all Drinking Subjects, and Regression Line with Brackets Enclosing 80% of the Points

TABLE A-14. SUMMARY OF ANALYSIS OF VARIANCE FOR 20 SOCIAL DRINKING SUBJECTS ON THE PURSUIT-TRACKING TESTER: PERCENTAGE OF CORRECT RESPONSES

Sources of Variance	Degrees of Freedom	Sum of Squares	Mean Squares	F Ratio
Total	139	697,232.0	5,016.06	
Test. Cond's(7)	6	96,976.0	16,162.66	6.55*
Subjects (20)	19	319,072.0	16,793.26	
T x S	114	281,184.0	2,466.52	

*p < 0.01

TABLE A-15. SUMMARY OF ANALYSIS OF VARIANCE FOR 12* REGISTRY DRINKING SUBJECTS ON THE PURSUIT-TRACKING TESTER: PERCENTAGE OF CORRECT RESPONSES

Sources of Variance	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio
Total	83	940,584.0	11,332.34	
Test Cond's(7)	6	259,312.0	43,218.66	9.28**
Subjects (12)	11	373,760.0	33,978.17	
T x S	66	307,504.0	4,659.15	

*One subject was dropped from the analysis because she became ill and did not complete the series.

**p < 0.01

A-2.3.5 Compensatory-Tracking Tester

A-2.3.5.1 Description of Subjects' Task on the Device - Developed by the Transportation Systems Center, this unit requires the operator to perform the compensatory-tracking task of keeping a randomly-driven pointer centered by turning a knob. The task runs for 43 seconds. The dependent variable is the integrated-absolute-position error (in volt-seconds). An absolute-error score which exceeds a pass/fail threshold results in failure. (This threshold must be set individually for each driver.)

A-2.3.5.2 Results - Subjects repeated the task five times for each of the seven testing conditions. Table A-16 gives mean BAQ attained, mean absolute-integrated-position error (in volt-seconds), standard deviation, and the number of data points per cell for each testing condition. The correlation coefficients of BAQ by performance are shown, along with the number of pairs and level of significance, for each group of drinking subjects. Training schedules and the motivation scheme used during testing are also listed.

No control subjects were tested on this device; a substantial number of registry subjects were run, however. Relatively few females participated, and again it was decided to ignore any gender effects and pool the registry and social subjects.

A summary of the analysis of variance for the integrated-absolute-position error scores for the 20 social subjects is reported in Table A-17. This analysis shows that only testing conditions ($F(6,114)=9.14$, $p < 0.01$), and not the repetitions within each trial ($F(4,76) = 0.65$, $p < 0.05$) were statistically significant. The Tukey WSD test showed that performance under the drink-3 condition was significantly poorer than that for all other testing conditions. No other significant mean differences were found.

TABLE A-16. SUMMARY OF PERFORMANCE ON THE COMPENSATORY-TRACKING TESTER

DOT-TSC	DAY 1	DAY 2	DAY 3 - TESTING PERFORMANCE IN ABSOLUTE INTEGRATED POSITION ERROR (IN VOLT-SECONDS) (Subjects performed 5 repetitions within each testing condition)								
Subjects	Training	Training	Control	Drink 1	Drink 2	Drink 3	Check 1	Check 2	Check 3	Correlation BAQ X Perf.	Motivation (Bonus Money)
Social Male (17)	Subjects Completed four sessions with 10 trials per session Total-40 trials	Subjects Completed four sessions with 10 trials per session Total-40 trials	0.017 268.27 35.10 85	0.033 253.65 36.95 85	0.078 273.04 43.85 85	0.105 307.47 70.80 85	0.081 287.45 39.86 85	0.091 264.69 36.94 85	0.043 262.19 40.23 85	0.233 P<0.01 (595)	50¢ could be earned on each test trial if a score was not over 110% of the control condition score (with no lower limits)
Social Female (3)			0.000 292.07 46.47 15	0.040 299.47 43.54 15	0.085 328.47 46.14 15	0.110 402.00 138.82 15	0.082 324.87 62.91 15	0.062 297.13 39.33 15	0.047 303.47 55.23 15	0.408 P<0.001 (105)	
Registry Male (9)			0.011 288.96 47.55 45	0.040 280.33 30.28 45	0.082 294.19 43.77 45	0.144 356.78 84.01 45	0.110 331.69 69.55 45	0.176 310.76 45.81 45	0.062 301.20 44.91 45	0.388 P<0.01 (315)	
Registry Female (3)			0.037 261.77 45.86 15	0.039 257.53 49.42 15	0.078 266.40 42.69 15	0.138 308.40 68.99 15	0.105 290.13 64.86 15	0.072 275.33 63.99 15	0.052 256.40 49.75 15	0.245 P<0.02 (105)	
Control Male Social (0)										(--)	
Control Female Social (0)										(--)	

TABLE A-16. SUMMARY OF PERFORMANCE ON THE COMPENSATORY-TRACKING TESTER (Continued)

DOT-TSC	DAY 1	DAY 2	DAY 3 - TESTING PERFORMANCE IN ABSOLUTE INTEGRATED POSITION ERROR (IN VOLT-SECONDS) (Subjects performed 5 repetitions within each testing condition)								
Subjects	Training	Training	Control	Drink 1	Drink 2	Drink 3	Check 1	Check 2	Check 3	Correlation BAQ X Perf.	Motivation (Bonus Money)
Registry (12)	Subjects Completed four sessions with 10 trials per session Total- 40 trials	Subjects Completed four sessions with 10 trials per session Total- 40 trials	0.008 282.12 48.24 60	0.039 274.78 36.71 60	0.081 287.78 45.14 60	0.143 343.43 82.81 60	0.109 319.80 69.49 60	0.086 301.88 52.68 60	0.065 289.85 50.33 60	0.351 P<0.01 (420)	50¢ could be earned on each test trial if a score was not over 110% of the control condition score (with no lower limits)
Social (20)			0.001 271.72 37.81 100	0.035 260.47 41.27 100	0.082 281.07 48.54 100	0.105 318.49 94.51 100	0.081 292.44 46.26 100	0.062 269.74 39.04 100	0.044 268.68 45.11 100	0.259 P<0.01 (700)	
Totals (32)			0.016 275.68 42.18 160	0.036 265.78 40.17 160	0.080 283.78 47.08 160	0.120 328.35 90.91 160	0.092 302.76 57.44 160	0.110 281.79 47.15 160	0.050 276.66 47.81 160	0.329 P<0.01 (1120)	
Females (6)			0.019 276.92 47.91 30	0.039 278.50 50.49 30	0.082 297.44 53.89 30	0.125 355.20 117.76 30	0.094 307.50 65.22 30	0.067 286.23 53.35 30	0.050 280.44 56.71 30	0.241 P<0.01 (210)	
Males (26)			0.015 275.43 40.88 130	0.035 262.89 36.93 130	0.079 280.36 44.81 130	0.101 324.54 78.90 130	0.091 302.76 55.95 130	0.120 280.64 45.70 130	0.050 275.69 45.70 130	0.355 P<0.01 (910)	

TABLE A-17. SUMMARY OF ANALYSIS OF VARIANCE FOR 20 SOCIAL DRINKING SUBJECTS ON THE COMPENSATORY-TRACKING TESTER

Sources of Variance	Degrees of Freedom	Sum of Squares	Mean Squares	F Ratio
Total	699	2,223,272.0	3,180.65	
Repetitions (5)	4	2,768.0	692.00	0.65
Testing Conditions (7)	6	231,968.0	38,661.33	9.14*
Subjects (20)	19	919,328.0	48,385.67	
R x T	24	42,824.0	1,784.33	
R x S	76	81,392.0	1,070.95	
T x S	114	482,280.0	4,230.52	
R x T x S	456	462,712.0	1,014.72	

*p < 0.01

A summary of the analysis of variance for the 12 registry subjects is reported in Table A-18. This analysis shows both testing conditions ($F(6,66)=8.84$, $p < 0.01$) and repetitions within each trial ($F(4,44)=4.22$, $p < 0.01$) to be statistically significant effects. The Tukey WSD test showed that performance under the drink-3 condition was significantly poorer than that for all other testing conditions. A Tukey analysis of the repetitions within each testing condition showed that performance improved significantly from the first through fifth repetitions.

A summary of analysis of variance for all 32 drinking subjects on the Compensatory-Tracking Tester is presented in Table A-19. This analysis shows that, with subjects pooled, both testing conditions ($F(6,186)=17.61$, $p < 0.01$) and repetitions within each testing condition ($F(4,124)=3.06$, $p < 0.01$) were statistically significant.

Figure A-17 presents the scatterplot of the absolute-integrated-position error (in volt-seconds) for all subjects as a function of BAQ (r_T (N=1120)=0.329, $p < 0.01$).

TABLE A-18. SUMMARY OF ANALYSIS OF VARIANCE FOR 12 REGISTRY DRINKING SUBJECTS ON THE COMPENSATORY-TRACKING TESTER

Sources of Variance	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio
Total	419	1,548,848.0	3,696.53	
Repetitions (3)	4	18,160.0	454.00	4.22*
Testing Conditions (7)	6	209,392.0	34,898.66	8.84*
Subjects (12)	11	690,104.0	62,736.72	
R x T	24	34,664.0	1,444.33	
R x S	44	47,280.0	1,074.54	
T x S	66	260,520.0	3,947.27	
R x T x S	264	288,728.0	1,093.67	

*p < 0.01

TABLE A-19. SUMMARY OF ANALYSIS OF VARIANCE FOR ALL 32 DRINKING SUBJECTS ON THE COMPENSATORY-TRACKING TESTER

Source of Variation	Sums of Squares	Degrees of Freedom	Mean Squares	F Ratio
Total	3874032.000	1119	3462.047	
Repetitions(5)	13680.000	4	3400.000	3.06*
Testing Conditions(7)	495144.000	6	71357.328	17.61*
Subjects(32)	1710464.000	31	55176.250	
R x T	50512.000	24	2104.667	
R x S	137648.000	124	1110.064	
T x S	753600.000	136	4051.612	
R x T x S	780064.000	744	1048.473	

*p < 0.01

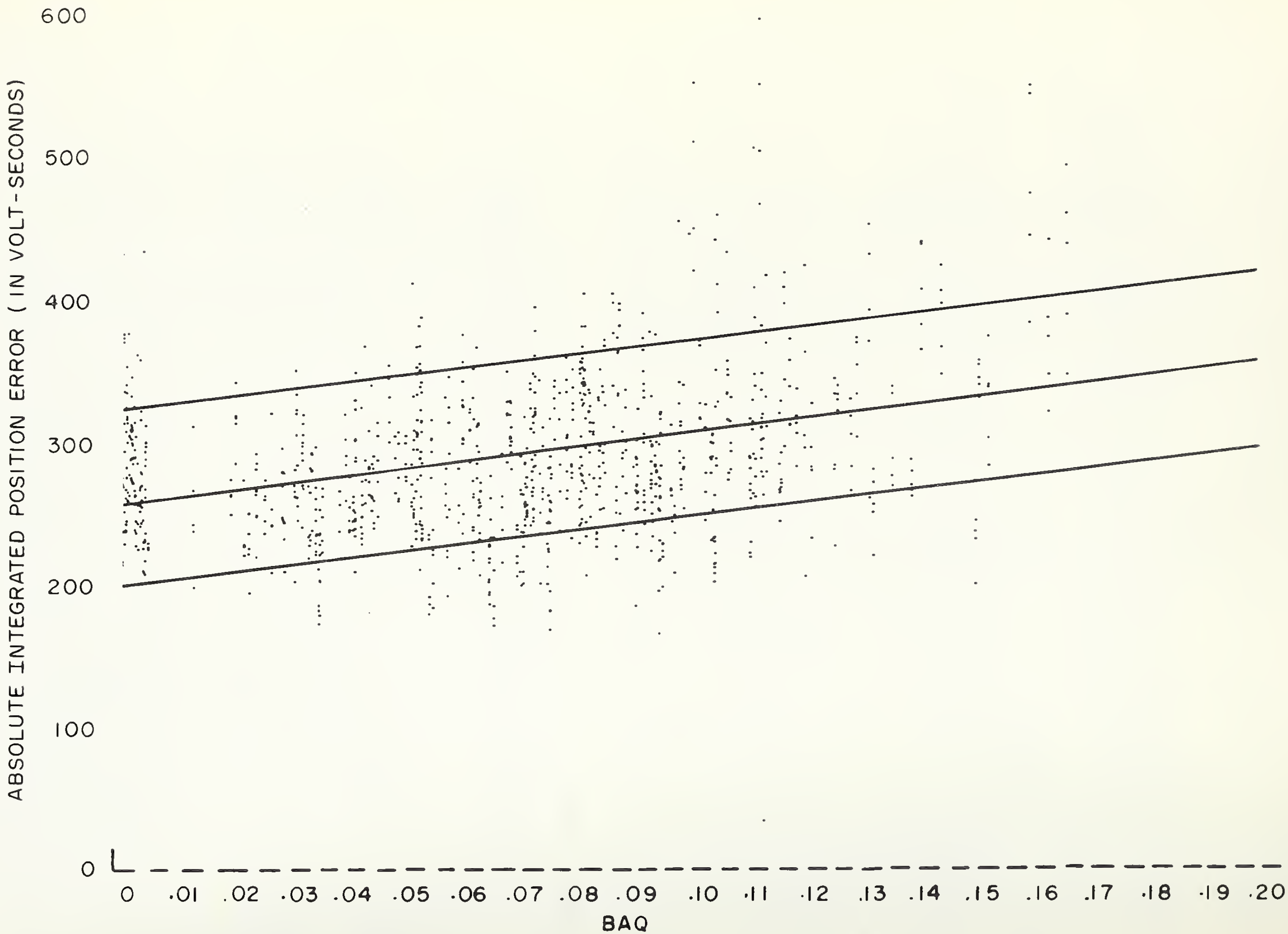

Figure A-17. Scatterplot of Absolute Integrated BAQ Position Error (in volt-seconds) on the Compensatory-Tracking Tester against BAQ for all Drinking Subjects, and Regression line with Brackets Enclosing 80% of the Points

A-2.3.6 Complex-Reaction Tester

A-2.3.6.1 Description of Subjects' Task on the Device - Developed by the Transportation Systems Center, this unit requires the operator to perform a complex-reaction task which has both compatible and incompatible stimulus/response combinations. Such a task is sensitive to reaction latency, information-processing ability, motor coordination, and attention. The operator is presented with a four-stimulus display, composed of four lights arranged as the corners of a rectangle. The display stimuli form two vertical pairs, since the horizontal dimension of the stimulus display is much greater than the vertical. The operator must respond to stimuli in the upper corners by pressing a button on the same side of the rectangle as the stimulus. This is considered a compatible response. The operator must respond to stimuli in the lower corners of the rectangle by pressing a button on the opposite side of the rectangle from the stimulus. This is considered an incompatible response. Pressing the wrong button or taking more than 0.9 seconds to respond is recorded as an error. Eight stimuli constitute a trial. Measures recorded are: total reaction time (in milliseconds) to responses on the same and opposite side, and total number of errors.

A-2.3.6.2 Results - Subjects repeated the test five times per testing condition. The results are presented in three sections: error data, same-reaction time, and opposite-reaction time.

a. Error Data

Table A-20 lists mean BAQ attained, mean number of errors, standard deviation, and the number of data points per cell. The correlation coefficients of BAQ by performance are shown for the number of pairs of data points, along with their level of significance, for each group of drinking subjects. The training criterion and the motivation scheme used during testing are also listed.

TABLE A-20. SUMMARY OF PERFORMANCE (MEAN NUMBER OF ERRORS) ON THE COMPLEX-REACTION TESTER

DOT-TSC	DAY 1	DAY 2 - TESTING PERFORMANCE IN MEAN NUMBER OF ERRORS (Subjects performed 5 repetitions per testing condition)								
Subjects	Training	Control	Drink 1	Drink 2	Drink 3	Check 1	Check 2	Check 3	Correlation BAO X Perf.	Motivation (Bonus Money)
Social Male (12)	Minimum of 10 practice trials until subject made fewer than 2 errors out of 8 light stimuli	0.000 0.95 1.545 60	0.034 0.75 0.968 60	0.085 1.40 1.532 60	0.107 1.62 1.530 60	0.082 1.20 1.459 60	0.054 0.75 1.002 60	0.039 0.90 1.311 60	0.163 P<0.01 (420)	10¢ per passing score on each repetition could be earned. One or fewer errors (error either pressing the wrong button or responding in more than 0.9 sec) per repetition constituted a passing score.
Social Female (5)		0.000 0.36 0.757 25	0.033 0.48 0.714 25	0.090 0.52 0.872 25	0.117 0.76 0.926 25	0.080 0.75 0.851 25	0.064 0.36 0.569 25	0.040 0.28 0.458 25	0.188 P<0.05 (170)	
Registry Male (0)										
Registry Female (1)		0.025 1.00 0.707 5	0.06 1.00 0.707 5	0.065 0.20 0.447 5	0.155 1.40 1.673 5	0.115 1.00 1.225 5	0.075 1.00 1.00 5	0.05 0.20 0.447 5	0.231 p > 0.05 (35)	
Control Male Social (2)		---- 0.80 0.79 10	---- 0.50 0.53 10	---- 0.70 0.82 10	---- 1.30 1.06 10	---- 0.70 1.06 10	---- 0.60 0.70 10	---- 0.60 0.52 10	(--)	
Control Female Social (1)		---- 0.40 0.55 5	---- 0.20 0.45 5	---- 0.40 0.55 5	---- 1.00 1.73 5	---- 1.60 0.89 5	---- 0.60 0.55 5	---- 1.20 0.84 5	(--)	

TABLE A-20. SUMMARY OF PERFORMANCE (MEAN NUMBER OF ERRORS) ON THE COMPLEX-REACTION TESTER (CONTINUED)

DOT-TSC	DAY 1	DAY 2 - TESTING PERFORMANCE IN MEAN NUMBER OF ERRORS (Subjects performed 5 repetitions per testing condition)								
Subjects	Training	Control	Drink 1	Drink 2	Drink 3	Check 1	Check 2	Check 3	Correlation BAQ X Perf.	Motivation (Bonus Money)
Registry (1)	Minimum of 10 practice trials until subject made fewer than 2 errors out of 8 light stimuli	0.025 1.00 0.707 5	0.06 1.00 0.707 5	0.065 0.20 0.447 5	0.155 1.40 1.673 5	0.115 1.00 1.225 5	0.075 1.00 1.00 5	0.05 0.20 0.447 5	0.231 N.S. (35)	10¢ per passing score on each repetition could be earned. One or fewer errors (error either pressing the wrong button or responding in more than 0.9 sec) per repetition constituted a passing score.
Social (17)		0.00 0.776 1.383 85	0.034 0.611 0.905 85	0.086 1.459 2.174 85	0.110 1.894 2.924 85	0.081 1.537 2.850 80	0.057 0.635 0.911 85	0.039 1.035 2.079 85	0.152 P<0.01 (590)	
Totals (18)		0.001 0.789 1.353 90	0.035 0.689 0.895 90	0.085 1.089 1.404 90	0.112 1.369 1.437 90	0.083 1.082 1.329 85	0.058 0.656 0.914 90	0.040 0.689 1.138 90	0.153 P<0.01 (625)	
Females (6)		0.004 0.467 0.776 30	0.038 0.567 0.728 30	0.086 0.467 0.822 30	0.116 0.867 1.076 30	0.086 0.800 0.913 25	0.066 0.467 0.682 30	0.042 0.267 0.454 30	0.218 P<0.01 (205)	
Males (12)		0.000 0.95 1.545 60	0.034 0.75 0.968 60	0.085 1.40 1.532 60	0.107 1.62 1.530 60	0.082 1.20 1.459 60	0.054 0.75 1.002 60	0.089 0.90 1.311 60	0.163 P<0.01 (420)	

Figure A-18 shows the mean number of errors for the 12 male social drinking subjects and the two male social control subjects as a function of testing conditions. A summary of the analysis of variance for the 12 male social drinking subjects is presented in Table A-21. This analysis shows only the testing conditions ($F(6,66)=3.56$, $p < 0.01$), not the repetitions within each trial ($F(4,44)=1.73$, $P > 0.05$), to be statistically significant effect. The Tukey WSD test for mean differences showed that performance for the drink-3 condition was significantly worse than that for all other testing conditions. No other significant mean differences were found.

Figure A-19 shows the mean number of errors for the five female social drinking subjects and the one female social control subject as a function of testing conditions. A summary of the analysis of variance for the mean number of errors for the five female social subjects is reported in Table A-22. This analysis shows that neither the testing conditions ($F(6,24)=1.87$, $p > 0.05$) nor the repetitions within each trial ($F(4,16)=0.92$, $p > 0.05$) had significant effects.

Figure A-20 presents the scatterplot of number of errors for all drinking subjects as a function of BAQ (r_T $(M=625)=0.153$, $p < 0.01$).

b. Same-Reaction Time Data

Table A-23 lists mean BAQ attained, mean time to complete a trial (in milliseconds), standard deviation, and the number of data points per cell. The correlation coefficients of BAQ with performance are shown, along with the number of pairs and level of significance, for each group of drinking subjects. (Note that control subjects received no alcohol.) The training criterion and the motivation scheme used during testing are also listed.

Figure A-21 presents the mean same-reaction times for the 12 male social drinking subjects and the two male social control subjects as a function of testing conditions. A summary of the analysis of variance for the 12 experimental subjects is presented

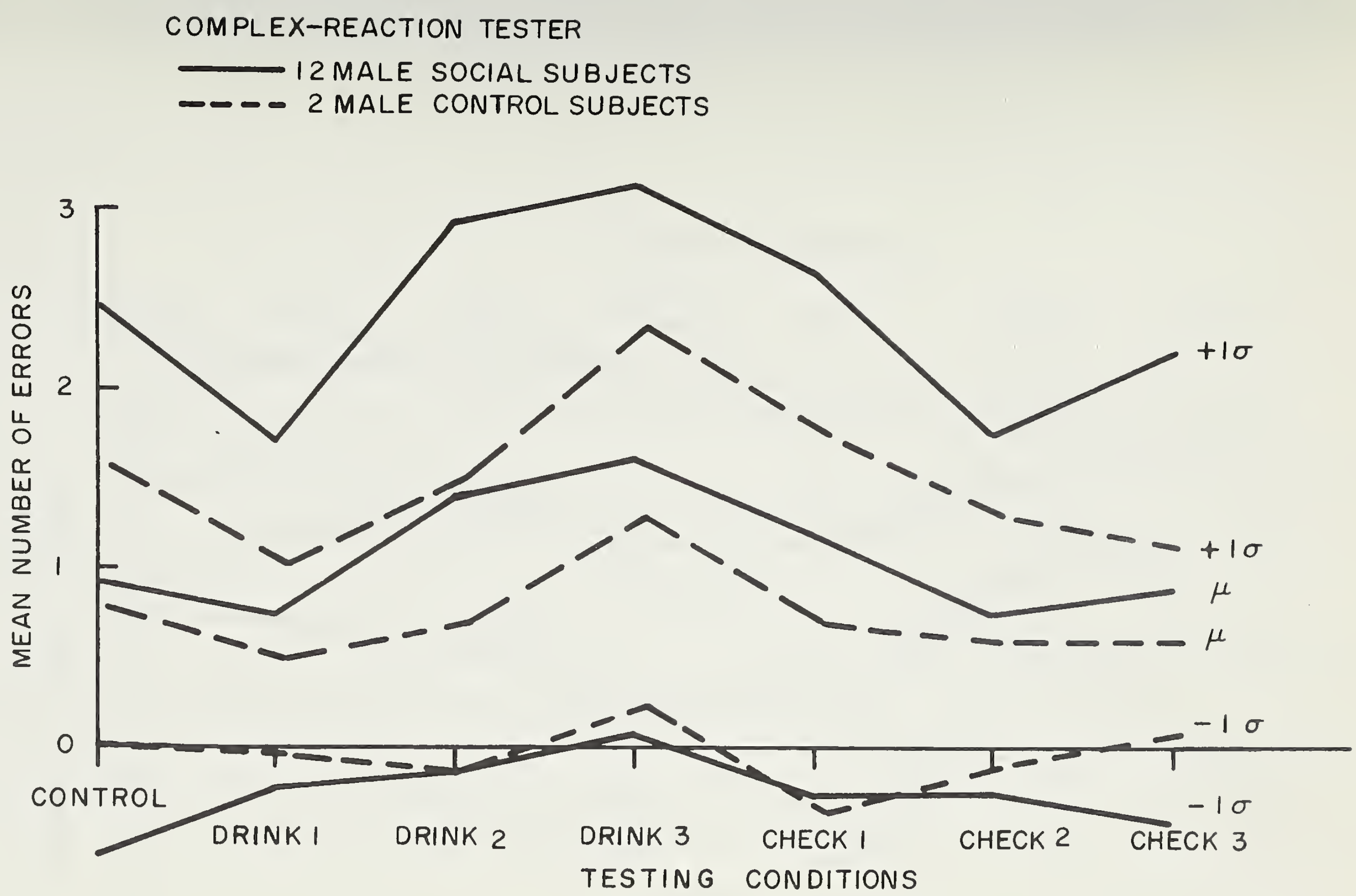

Figure A-18. Peformance on the Complex-Reaction Tester Measured as Mean Number of Errors as a Function of Testing Conditions for the 12 Male Social Drinking and the Two Male Control Subjects

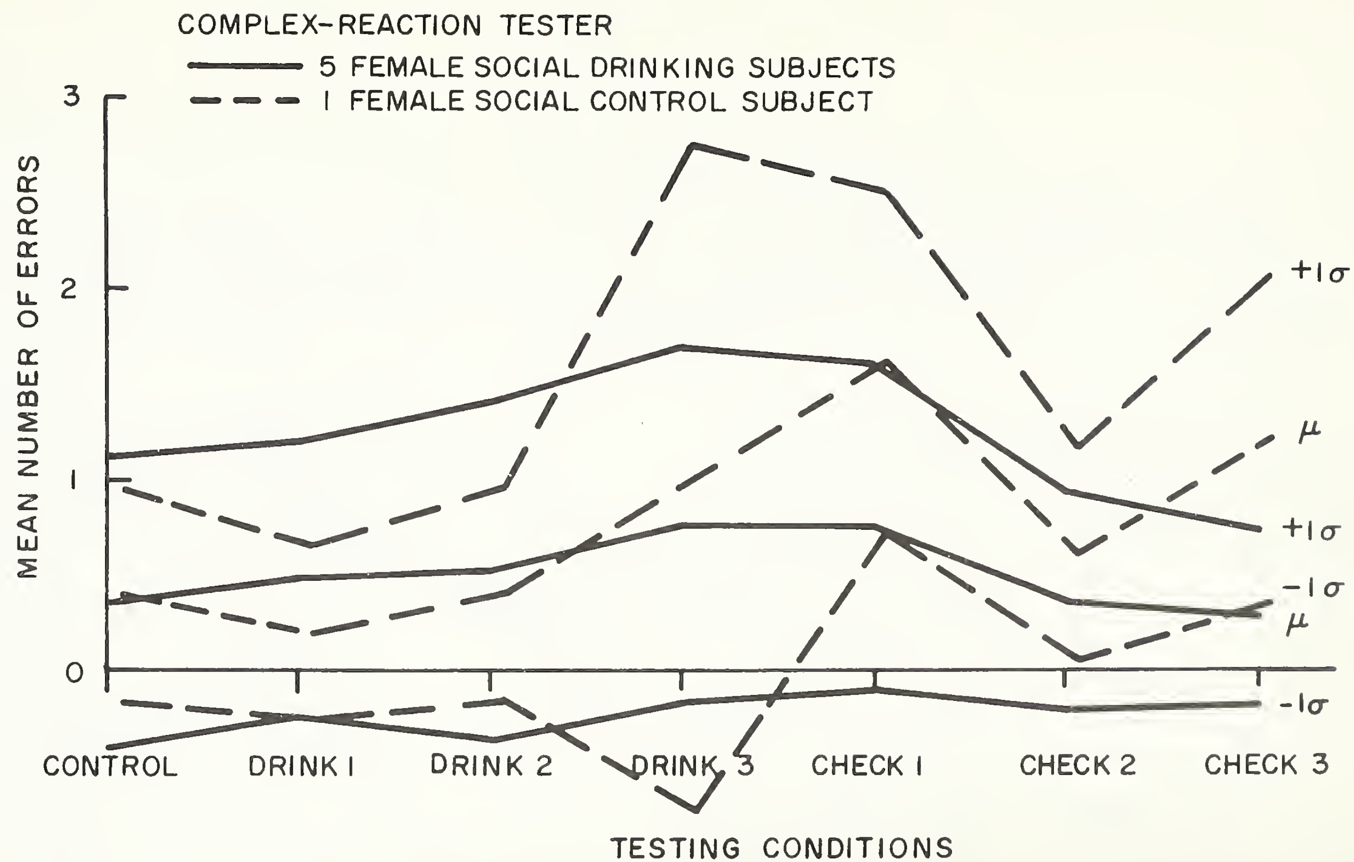

Figure A-19. Performance on the Complex-Reaction Tester Measured as Mean Number of Errors as a Function of Testing Conditions for the Five Female Social Drinking and the One Female Control Subjects

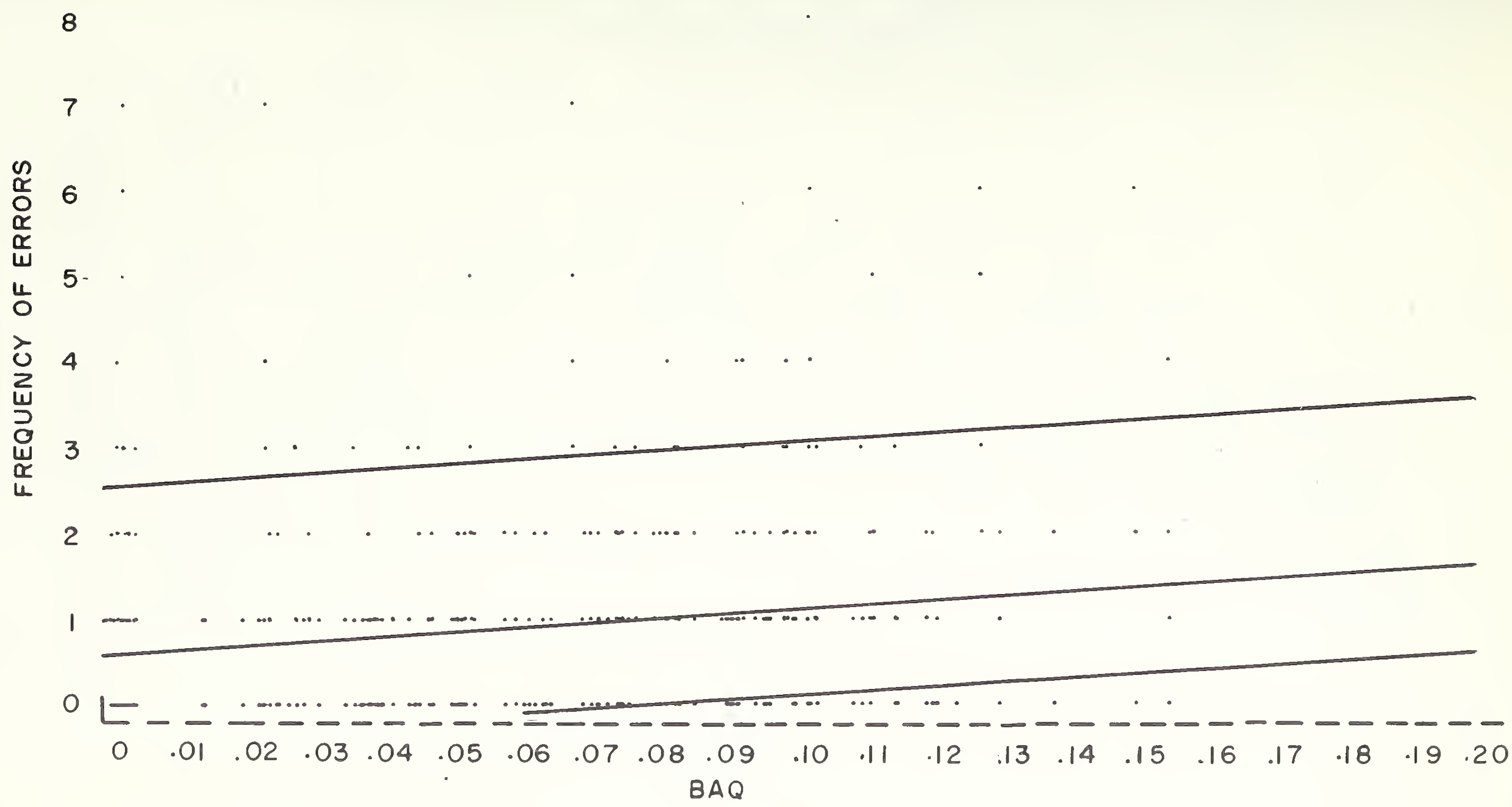

Figure A-20. Scatterplot of Number of Errors on the Complex-Reaction Tester against BAQ for all Drinking Subjects, and Regression Line with Brackets Enclosing 80% of the Points

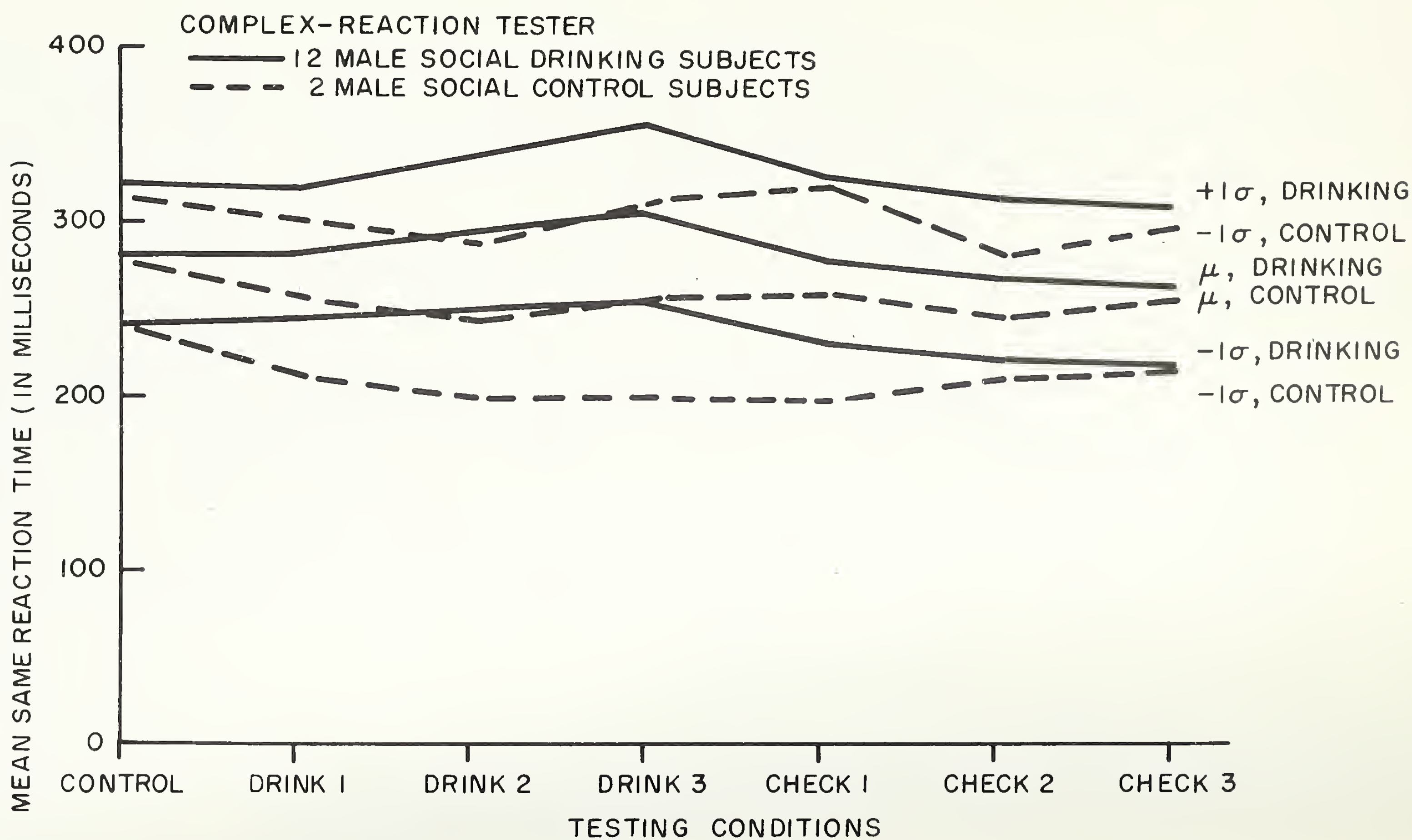

Figure A-21. Performance on the Complex-Reaction Tester Measured as Same-Reaction Time (in Milliseconds) as a Function of Testing Conditions for the 12 Male Social Drinking Subjects and the Two Male Control Subjects

TABLE A-21. SUMMARY OF ANALYSIS OF VARIANCE (NUMBER OF ERRORS) FOR 12 MALE SOCIAL DRINKING SUBJECTS ON THE COMPLEX-REACTION TESTER

Sources of Variance	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio
Total	419	799.25	1.91	
Repetitions (3)	4	7.25	1.81	1.73
Testing Conditions (7)	6	40.31	6.72	3.56*
Subjects (12)	11	342.28	31.12	
R x T	24	20.02	0.83	
R x S	44	46.01	1.05	
T x S	66	124.66	1.89	
R x T x S	264	218.73	0.83	

*p < 0.01

TABLE A-22. SUMMARY OF ANALYSIS OF VARIANCE (NUMBER OF ERRORS) FOR FIVE FEMALE SOCIAL DRINKING SUBJECTS ON THE COMPLEX-REACTION TESTER

Sources of Variance	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio
Total	174	96.49	0.56	
Repetitions (3)	4	1.85	0.46	0.92
Testing Conditions (7)	6	5.14	0.86	1.87
Subjects (5)	4	10.27	2.57	
R x T	24	9.65	0.40	
R x S	16	8.07	0.50	
T x S	24	11.08	0.46	
R x T x S	96	50.43	0.52	

TABLE A-23. SUMMARY OF PERFORMANCE (SAME-REACTION TIME) ON THE COMPLEX REACTION TESTER

DOT-TSC	DAY 1	DAY 2 - TESTING PERFORMANCE IN MEAN REACTION TIME (IN MILLISECONDS) (Subjects performed 5 repetitions per testing condition)								
Subjects	Training	Control	Drink 1	Drink 2	Drink 3	Check 1	Check 2	Check 3	Correlation BAQ X Perf.	Motivation (Bonus Money)
Social Male (12)	Minimum of 10 practice trials until subject made fewer than 2 errors out of 8 light stimuli	0.000 281.78 40.79 60	0.034 280.92 37.54 60	0.085 294.00 43.35 60	0.107 303.84 50.96 60	0.082 277.50 47.66 60	0.054 267.00 46.76 60	0.039 262.75 45.25 60	0.088 N.S. (420)	10¢ per passing score on each repetition could be earned. One or fewer errors (error either pressing the wrong button or responding in more than 0.9 sec) per repetition constituted a passing score.
Social Female (5)		0.000 266.40 30.30 25	0.033 270.44 34.60 25	0.090 265.68 30.21 25	0.117 285.64 40.81 25	0.080 278.10 36.28 20	0.064 276.56 32.13 25	0.040 261.62 33.30 25	0.155 N.S. (170)	
Registry Male (0)										
Registry Female (1)		0.025 272.60 21.20 3	0.060 280.60 23.158 5	0.065 252.80 9.577 5	0.155 364.40 21.916 5	0.115 288.00 31.073 5	0.075 293.20 36.527 5	0.05 257.40 22.007 5	0.450 P<0.02 (35)	
Control Male Social (2)		---- 277.10 37.17 10	---- 256.70 44.31 10	---- 243.40 44.11 10	---- 256.50 56.37 10	---- 258.80 61.03 10	---- 245.50 35.43 10	---- 255.90 40.96 10	(--)	
Control Female Social (1)		---- 292.40 39.20 5	---- 297.20 33.12 5	---- 250.00 20.04 5	---- 285.60 37.39 5	---- 283.60 24.83 5	---- 253.00 28.64 5	---- 273.20 26.52 5	(--)	

TABLE A-23. SUMMARY OF PERFORMANCE (SAME-REACTION TIME) ON THE COMPLEX-REACTION TESTER (Continued)

DOT-TSC	DAY 1	DAY 2 - TESTING PERFORMANCE IN MEAN REACTION TIME (IN MILLISECONDS) (Subjects performed 5 repetitions per testing condition)								
Subjects	Training	Control	Drink 1	Drink 2	Drink 3	Check 1	Check 2	Check 3	Correlation BAQ X Perf.	Motivation (Bonus Money)
Registry (1)	Minimum of 10 practice trials until subject made fewer than 2 errors out of 8 light stimuli	0.025 272.60 21.20 5	0.060 280.60 23.158 5	0.065 252.80 9.577 5	0.155 304.40 21.916 5	0.115 288.00 31.073 5	0.075 293.20 36.527 5	0.05 257.40 22.007 5	0.450 P<0.02 (35)	10¢ per passing score on each repetition could be earned. One or fewer errors (error either pressing the wrong button or responding in more than 0.9 sec) per repetition constituted a passing score.
Social (17)		0.00 277.58 35.52 85	0.034 275.19 36.62 85	0.086 280.95 40.98 85	0.110 291.54 48.11 85	0.081 278.90 44.87 80	0.057 268.02 44.28 85	0.039 259.45 41.92 85	0.101 P<0.05 (590)	
Totals (18)		0.001 277.00 37.67 90	0.035 272.90 36.10 90	0.085 283.84 41.38 90	0.112 298.81 47.54 90	0.083 278.26 44.11 85	0.058 271.11 43.91 90	0.040 262.17 40.99 90	0.115 P<0.01 (625)	
Female (6)		0.004 267.43 28.76 30	0.038 272.13 32.86 30	0.086 263.70 28.08 30	0.116 288.77 38.67 30	0.086 280.08 34.92 25	0.066 279.33 36.94 30	0.042 261.00 31.52 30	0.238 P<0.01 (205)	
Males (12)		0.000 281.78 40.79 60	0.034 280.92 37.54 60	0.085 294.00 43.35 60	0.107 303.83 50.96 60	0.082 277.50 47.66 60	0.051 267.00 46.76 60	0.039 262.75 45.25 60	0.088 N.S. (420)	

in Table A-24. Only testing conditions ($F(6,44)=6.87$, $p < 0.01$), and not the repetitions within each testing condition ($F(4,24)= 0.57$, $p > 0.05$), was statistically significant. A Tukey WSD test showed no significant differences between the control condition and the drink-3 condition, but reaction times were significantly worse ($p < 0.05$) for the check-3 condition.

TABLE A-24. SUMMARY OF ANALYSIS OF VARIANCE (SAME-REACTION TIME) FOR 12 MALE SOCIAL SUBJECTS ON THE COMPLEX-REACTION TESTER

Sources of Variance	Degrees of Freedom	Sums of Squares	Mean Square	F Ratio
Total	419	884,572.0	2,111.15	
Repetitions (5)	4	1,196.0	299.00	0.57
Testing Conditions (7)	6	55,480.0	9,246.67	6.87*
Subjects (12)	11	540,424.0	49,129.44	
R x T	24	11,068.0	461.17	
R x S	44	23,296.0	529.45	
T x S	66	88,884.0	1,346.73	
R x T x S	264	164,224.0	622.06	

*p < 0.01

Figure A-22 shows the mean same-reaction times for the five female social subjects and the one female social control subject as a function of testing condition. A summary of the analysis of variance for the 25 experimental subjects is presented in Table A-25. This analysis shows that neither the testing conditions ($F(6,24)=1.13$, $p > 0.05$), nor the repetitions within trials ($F(4,16)=1.94$, $p > 0.05$), were significant.

Finally, Figure A-23 presents the scatterplot of mean same-reaction times for all drinking subjects as a function of BAQ (r_T $(N=625)=0.115$, $p < 0.01$).

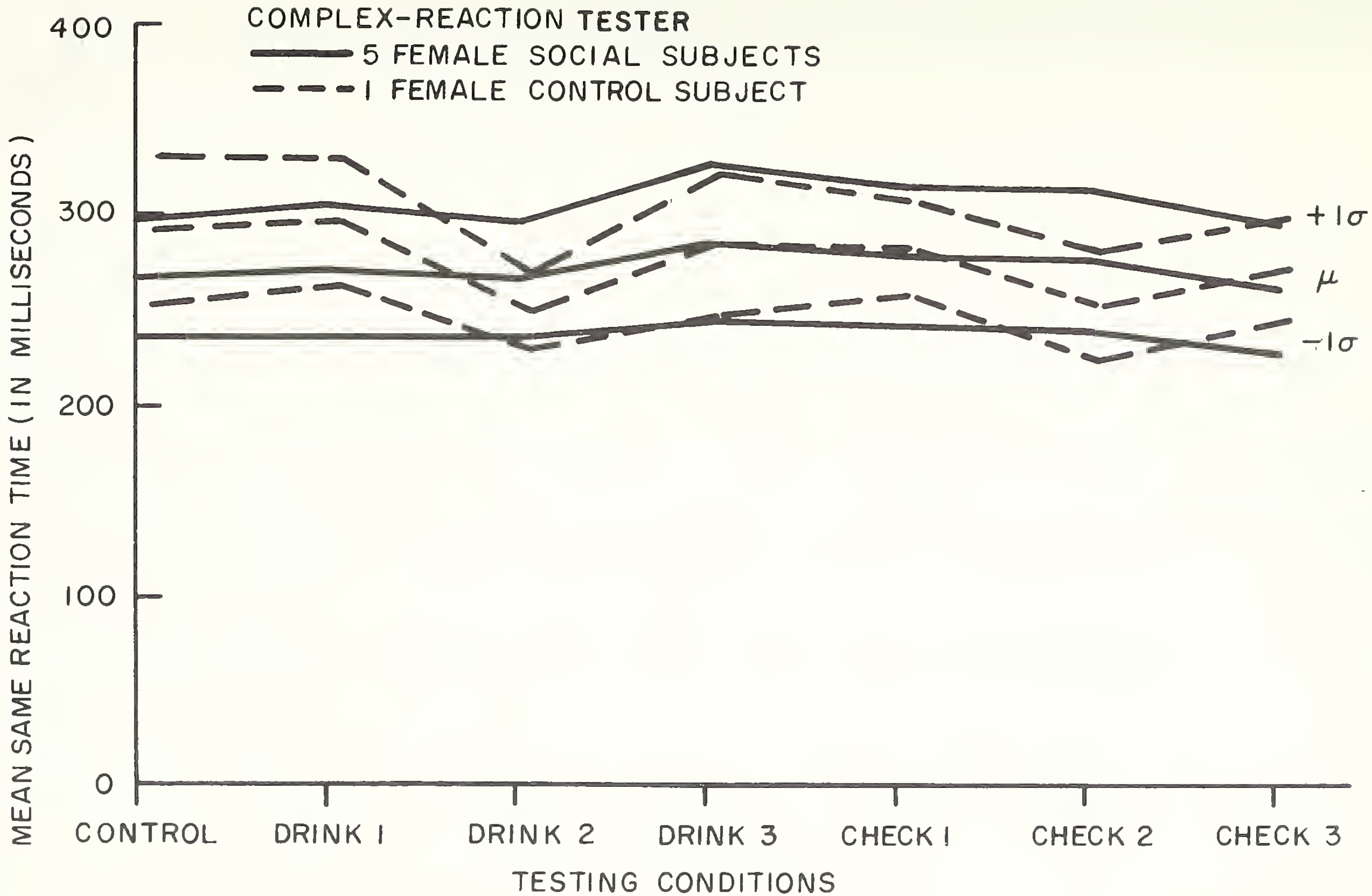

Figure A-22. Performance on the Complex-Reaction Tester Measured as Same-Reaction Time (in Milliseconds) as a Function of Testing Conditions for the Five Female Social Drinking Subjects and the One Female Control Subject

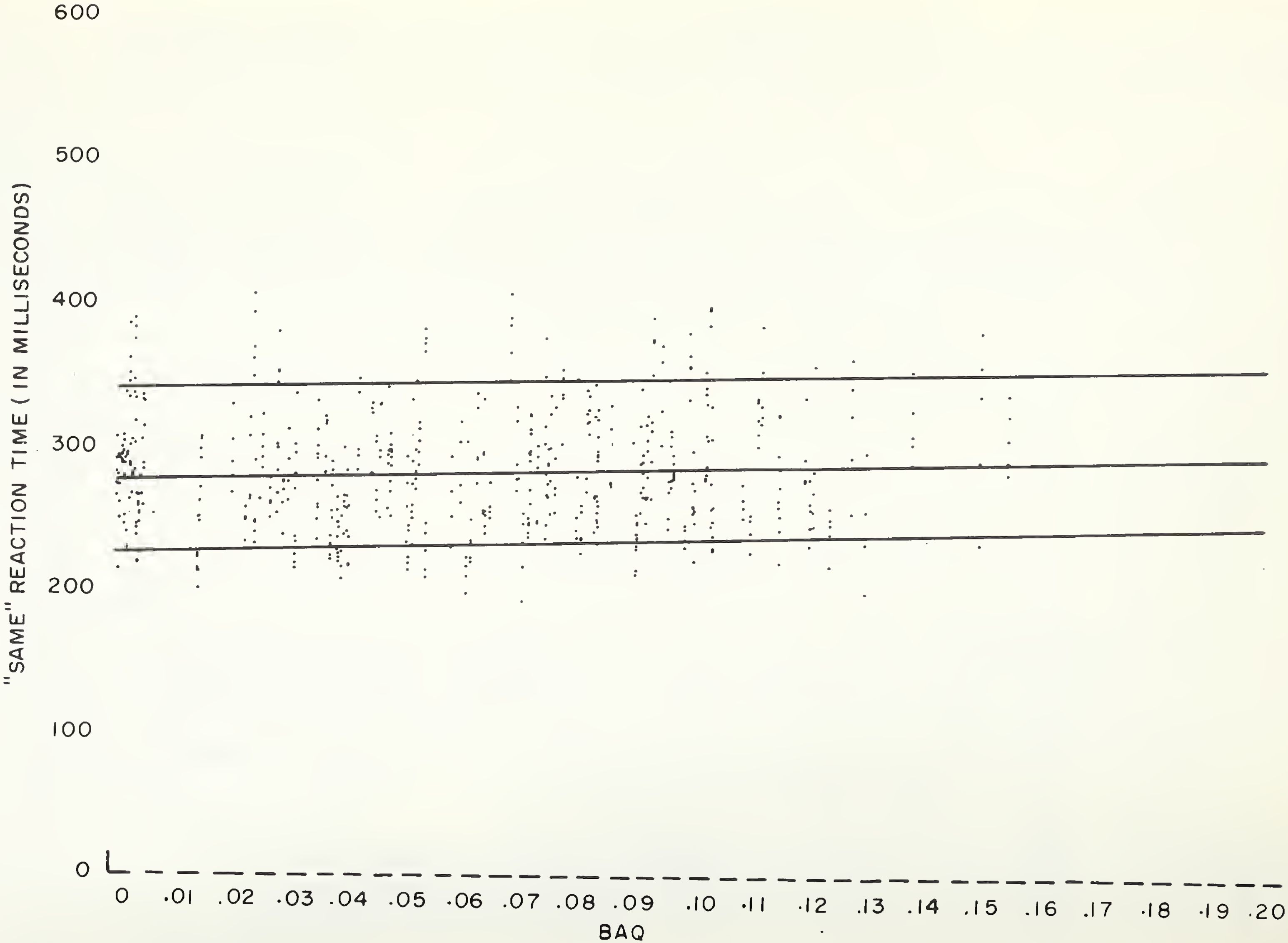

Figure A-23. Scatterplot of Same-Reaction Time (in milliseconds) on the Complex Reaction Tester against BAQ for all Drinking Subjects, and Regression Line with Brackets Enclosing 80% of the Points

TABLE A-25. SUMMARY OF ANALYSIS OF VARIANCE (SAME-REACTION TIME) FOR FIVE FEMALE SOCIAL DRINKING SUBJECTS ON THE COMPLEX-REACTION TESTER

Sources of Variance	Degrees of Freedom	Sums of Squares	Mean Square	F Ratio
Total	174	207,738.0	1,193.90	
Repetitions (5)	4	1,579.0	392.50	1.13
Testing Conditions (7)	6	10,396.0	1,732.67	1.94
Subjects (5)	4	95,592.0	23,898.00	
R x T	24	14,926.0	621.92	
R x S	16	5,578.0	348.62	
T x S	24	21,472.0	894.67	
R x T x S	96	58,204.0	696.29	

c. Opposite-Reaction Time Data

Table A-26 lists mean BAQ attained, mean time to complete a trial (in milliseconds), standard deviation, and the number of data points per cell. The correlation coefficients of BAQ with performance are shown, along with the number of pairs and level of significance, for each group of drinking subjects. (Note that control subjects received no alcohol). Training criteria and the motivation scheme used during testing are also listed.

Figure A-24 shows the mean opposite-reaction times for the 12 male social drinking subjects and the two male social control subjects as a function of testing condition. A summary of the analysis of variance for the 12 male drinking subjects is presented in Table A-27. This analysis shows that only the testing conditions ($F(6,66)=2.45$, $p < 0.05$), and not the repetitions within trials ($F(4,44)=1.62$, $p > 0.05$), was significant. A Tukey WSD test for these subjects showed that performance on the check-3 condition was significantly faster ($p < 0.05$) than on all other conditions. No other significant differences were found.

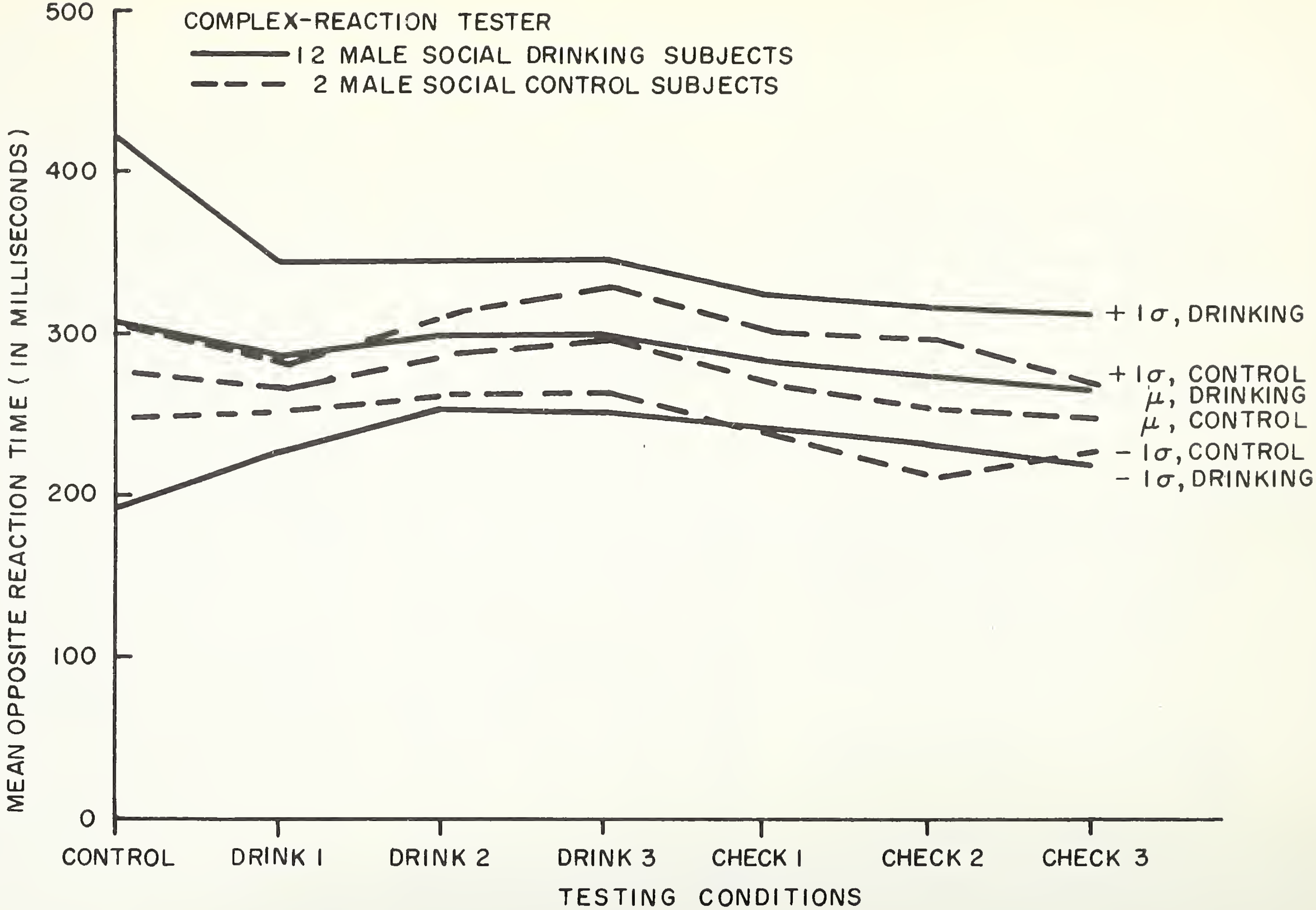

Figure A-24. Performance on the Complex-Reaction Tester for Opposite-Reaction Time (in milliseconds) as a Function of Testing Condition for the 12 Male Social Drinking Subjects and the Two Male Control Subjects

TABLE A-26. SUMMARY OF PERFORMANCE (OPPOSITE-REACTION TIME) ON THE COMPLEX-REACTION TESTER

DOT-TSC	DAY 1	DAY 2 - TESTING PERFORMANCE IN MEAN REACTION TIME (IN MILLISECONDS). (Subjects performed 5 repetitions per testing condition)								
Subjects	Training	Control	Drink 1	Drink 2	Drink 3	Check 1	Check 2	Check 3	Correlation BAQ X Perf.	Motivation (Bonus Money)
Social Male (12)	Minimum of 10 practice trials until subject made fewer than 2 errors out of 8 light stimuli.	0.000 305.85 114.19 60	0.034 283.87 58.74 60	0.085 297.26 45.25 60	0.107 297.60 47.44 60	0.082 280.68 41.13 60	0.054 271.90 42.66 60	0.039 262.85 46.30 60	0.015 N.S. (420)	25¢ per passing score on each repetition could be earned. One or fewer errors (error either pressing wrong button or responding in more than 0.9 sec) per repetition constituted a passing score.
Social Female (5)		0.000 269.20 22.34 25	0.033 265.84 26.22 25	0.090 269.20 29.21 25	0.117 285.52 37.87 25	0.080 288.60 34.93 20	0.064 263.32 27.66 25	0.04 255.88 27.78 25	0.222 P<.01 (170)	
Registry Male (0)									( )	
Registry Female (1)		0.025 315.80 16.814 5	0.06 315.80 21.159 5	0.065 292.40 8.849 5	0.155 341.60 28.378 5	0.115 319.20 34.723 5	0.075 316.40 22.030 5	0.05 325.60 41.633 5	0.397 P<.02 (35)	
Control Male Social (2)		---- 276.00 27.79 10	---- 265.90 14.11 10	---- 286.60 24.76 10	---- 295.30 33.01 10	---- 268.10 31.87 10	---- 252.70 42.69 10	---- 246.50 21.06 10	(--)	
Control Female Social (1)		---- 281.20 10.94 5	---- 252.80 12.83 5	---- 238.60 23.67 5	---- 277.60 43.34 5	---- 278.60 34.85 5	---- 266.00 19.39 5	---- 270.00 18.07 5	(--)	

TABLE A-26. SUMMARY OF PERFORMANCE (OPPOSITE-REACTION TIME) ON THE COMPLEX-REACTION TESTER (Continued)

DOT-TSC	DAY 1	DAY 2 - TESTING PERFORMANCE IN MEAN REACTION TIMES (IN MILLISECONDS). (Subjects performed 5 repetitions per testing condition)								
Subjects	Training	Control	Drink 1	Drink 2	Drink 3	Check 1	Check 2	Check 3	Correlation BAQ X Perf.	Motivation (Bonus Money)
Registry (1)	Minimum of 10 practice trials until subject made fewer than 2 errors out 8 light stimuli	0.025 315.80 16.814 5	0.06 315.80 21.159 5	0.065 292.40 8.849 5	0.155 341.60 28.378 5	0.115 319.20 34.723 5	0.075 316.40 22.030 5	0.05 325.60 41.633 5	0.397 P<.02 (35)	10¢ per passing score on each repetition could be earned. One or fewer errors (error either pressing the wrong button or responding in more than 0.9 sec.) per repetition constituted a passing score.
Social (17)		0.000 293.60 98.31 85	0.034 278.57 51.85 85	0.086 289.01 42.99 85	0.110 294.05 44.96 85	0.081 282.66 39.60 80	0.057 269.37 38.89 85	0.039 260.57 41.70 85	0.012 N.S. (590)	
Totals (18)		0.001 294.83 95.72 90	0.035 280.64 51.29 90	0.085 289.20 41.81 90	0.112 296.69 45.43 90	0.083 284.41 40.09 85	0.058 271.99 39.58 90	0.040 264.18 44.09 90	0.046 N.S. (625)	
Females (6)		0.004 272.80 28.89 30	0.038 274.17 31.45 30	0.086 273.67 28.18 30	0.116 294.87 41.83 30	0.086 294.72 36.37 25	0.066 272.17 33.24 30	0.042 266.83 39.90 30	0.295 p<.01 (205)	
Males (12)		0.000 305.85 114.19 60	0.034 283.87 58.74 60	0.085 297.26 45.25 60	0.107 297.60 47.44 60	0.082 280.68 41.13 60	0.054 271.90 42.66 60	0.039 262.85 46.30 60	0.015 N.S. (420)	

TABLE A-27. SUMMARY OF ANALYSIS OF VARIANCE OF THE OPPOSITE-REACTION TIME RESPONSE ON THE COMPLEX-REACTION TESTER

Sources of Variance	Degrees of Freedom	Sum of Squares	Mean Square	F Ratio
Total	419	1,645,264.0	3,926.64	
Repetitions (5)	4	14,848.0	3,712.00	1.62
Testing Conditions (7)	6	85,344.0	14,224.0	2.45*
Subjects (12)	11	556,688.0	50,607.99	
R x T	24	42,128.0	1,755.33	
R x S	44	100,824.0	2,291.45	
T x S	66	383,704.0	5,813.70	
R x T x S	264	461,728.0	1,748.97	

*$p < 0.05$

Figure A-25 shows the mean opposite-reaction times for the five female social drinking subjects and the one female social control subject as a function of testing conditions. A summary of the analysis of variance for the five experimental subjects is presented in Table A-28. This analysis shows that only the testing conditions ($F(6,24)=84$, $p < 0.01$), and not repetitions within trials ($F(4,16)=1.83$, $p > 0.05$), was significant. The Tukey WSD test showed the means for the drink-3 and Check-1 conditions to be significantly greater ($p < 0.05$) than that for all other conditions.

Figure A-26 presents the scatterplot of mean opposite-reaction time data for all drinking subjects as a function of BAQ (r_T $(625)=0.046$, $p > 0.05$).

d. Same- and Opposite-Reaction Times

Figure A-27 shows the pooled mean same- and opposite-reaction times for the 12 social male drinking subjects as a function of testing conditions. Figure A-28 presents the means for the five social female drinking subjects. A Tukey WSD test showed no significant difference between the same-and opposite-reaction times for either male or female social subjects.

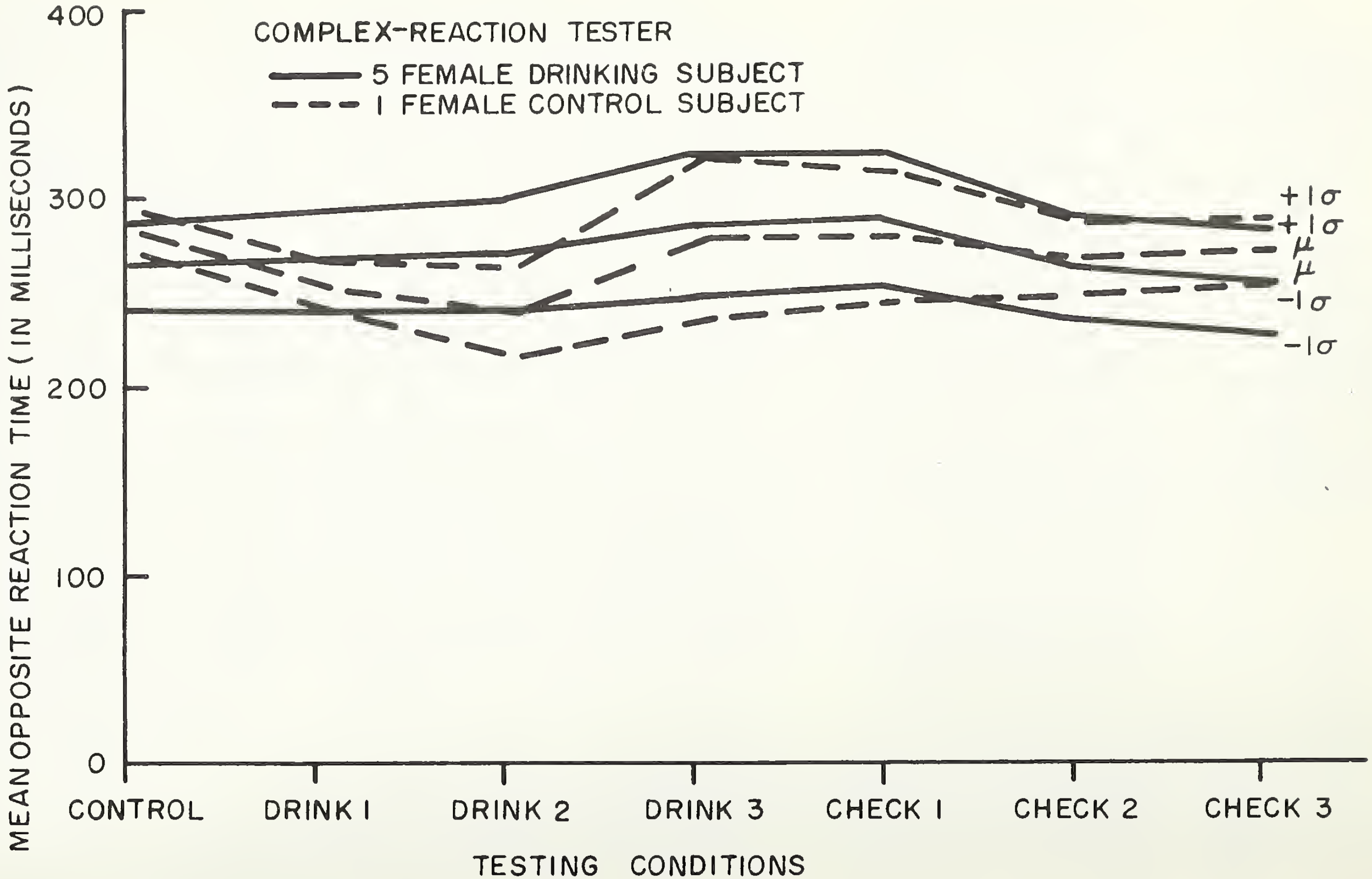

Figure A-25. Performance on the Complex-Reaction Tester for Opposite-Reaction Time (in milliseconds) as a Function of Testing Condition for the Five Female Social Drinking Subjects and the One Female Control Subject

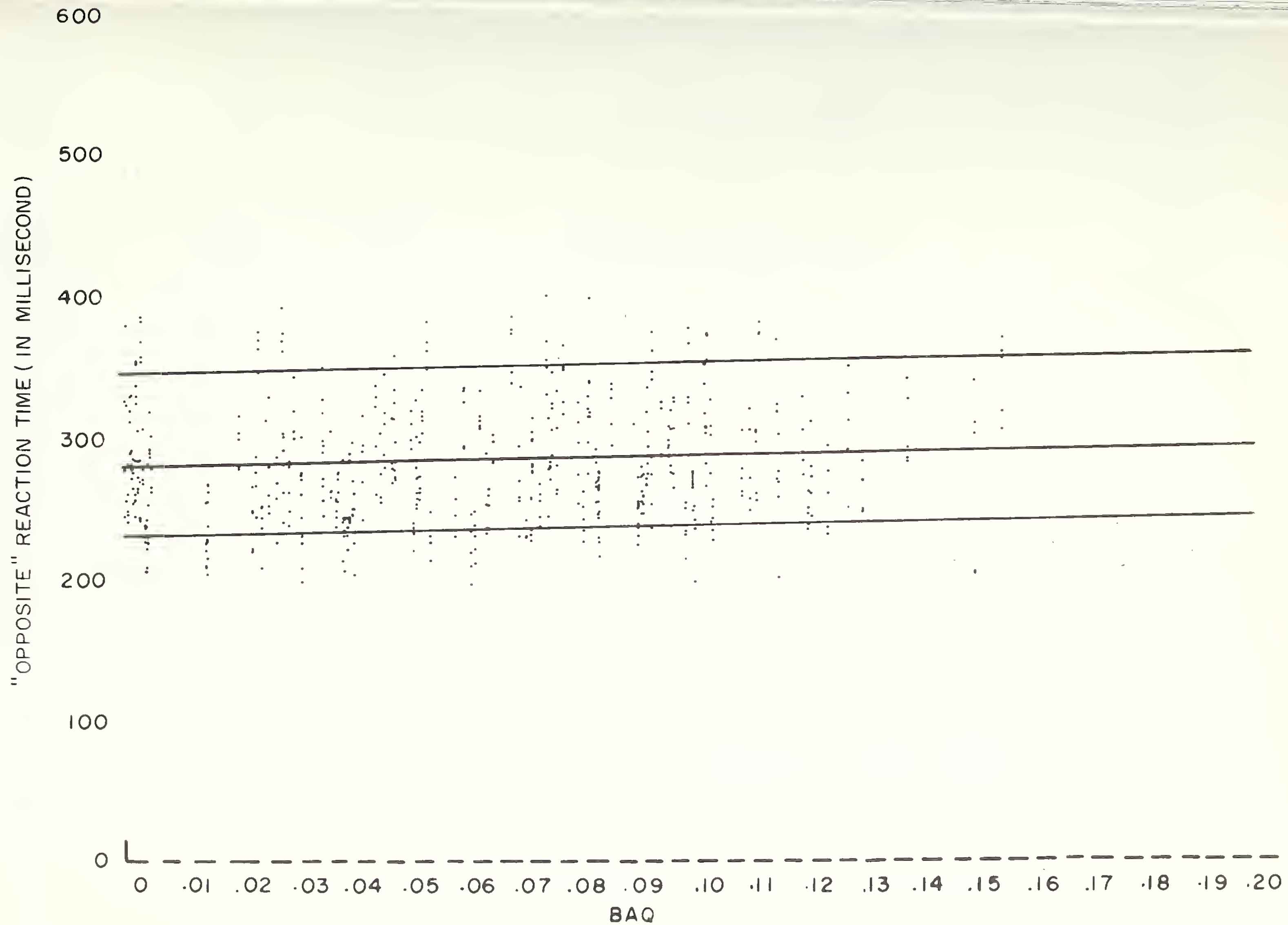

Figure A-26. Scatterplot of Opposite-Reaction Times (in milliseconds) on the Complex-Reaction Tester against BAQ for all Drinking Subjects, and Regression Line with Brackets Enclosing 80% of the Points

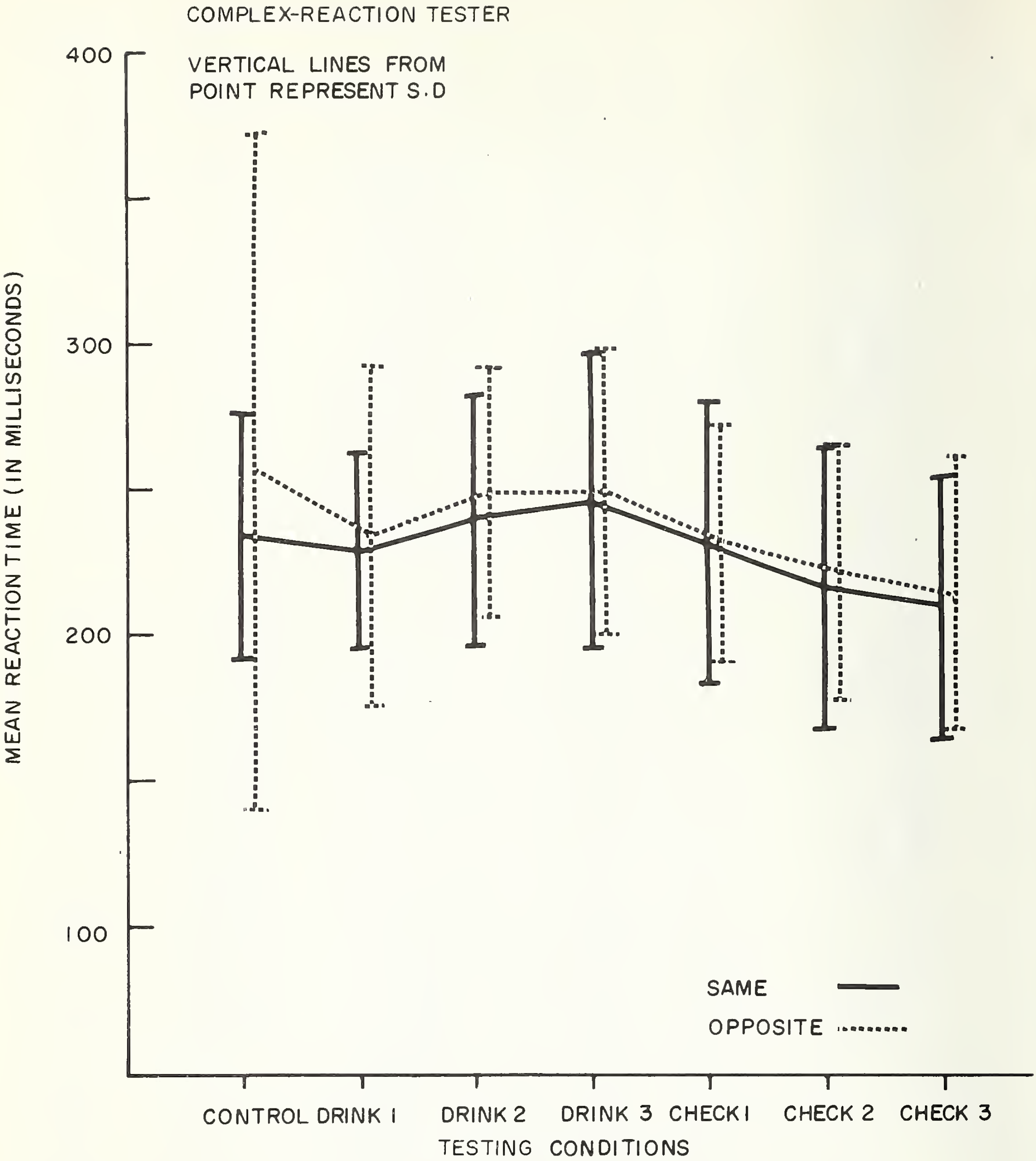

Figure A-27. Performance on the Complex-Reaction Tester Comparing Same- and Opposite-Reaction Times for the 12 Male Social Drinking Subjects

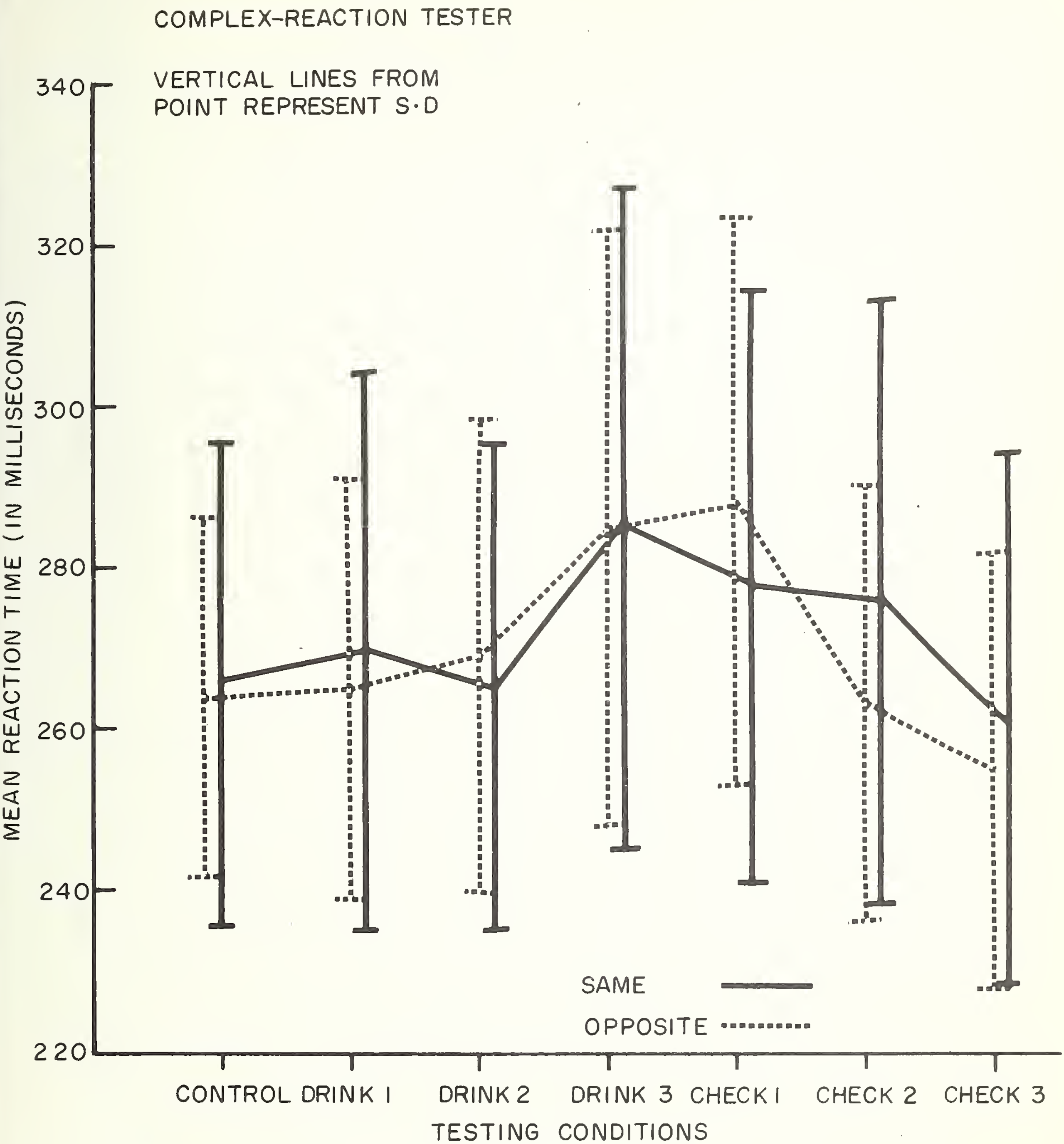

Figure A-28. Performance on the Complex-Reaction Tester Comparing Same- and Opposite-Reaction Times for the Five Female Social Drinking Subjects

TABLE A-28. SUMMARY OF ANALYSIS OF VARIANCE (OPPOSITE-REACTION TIME) FOR FIVE FEMALE SOCIAL DRINKING SUBJECTS ON THE COMPLEX-REACTION TESTER

Sources of Variance	Degrees of Freedom	Sum of Squares	Mean Square	F Ratio
Total	174	164,345.0	944.56	
Repetitions (5)	4	2,454.0	613.50	1.83
Testing Conditions (7)	6	20,894.0	3,482.33	4.84*
Subjects (5)	4	68,508.0	17,127.00	
R x T	24	10,768.0	448.67	
R x S	16	5,372.0	335.75	
T x S	24	17,258.0	719.08	
R x T x S	96	39,100.0	407.29	

*$p < 0.01$

A-2.3.7 <u>Phystester</u>

A-2.3.7.1 <u>Description of Subjects' Task on the Device</u> - Developed by the Delco Electronic Division of General Motors[6], this unit requires that the operator perform a divided-attention task. The operator must first enter an assigned 5-digit number on a panel of numbered push-buttons (numbers 0-9) similar to that on a Touch-Tone telephone. If this is done correctly, a random five-digit number is displayed for 1.5 seconds. The operator must key in this five-digit sequence on the numbered panel within 3.5 seconds. At some time during this process, a "brake" signal appears on the display and the subject must hit the brake pedal within one second.

A-2.3.7.2 <u>Results</u> - Subjects completed three repetitions for each of the seven testing conditions. Table A-29 lists mean BAQ attained, modal and median number of successful trials out of three reptitions, and number of data points per cell. The

TABLE A-29. SUMMARY OF PERFORMANCE ON THE PHYSTESTER DEVICE

GENERAL MOTORS	DAY 1	DAY 2	DAY 3 - TESTING PERFORMANCE IN MODAL AND MEDIAN NUMBER OF PASSES OUT OF 3 REPETITIONS) (Subjects performed 3 repetitions per testing condition)								
Type and No. of Subjects	Training	Training	Control	Drink 1	Drink 2	Drink 3	Check 1	Check 2	Check 3	Correlation BAQ X Perf.	Motivation (Bonus Money)
Social Male (15)	200 trials starting at a higher display and reaction time, limit such as 3.0/4.5 sec and working towards 1.5/3.5 sec. (4 errors of 50 trials each.)	200 trials again working towards a goal of mode: median: 1.5/3.5 sec. (4 sessions of 50 trials each.)	0.002 3 3 15	0.032 3 2 15	0.078 3 2 15	0.103 0 1 15	0.080 3 3 15	0.061 3 3 15	0.042 3 3 15	-.324 $p < 0.001$ (105)	20¢ per passing score on each repetition.
Social Female (5)			0.000 3 3 5	0.036 3 3 5	0.083 2 2 5	0.116 2 2 5	0.088 3 3 5	0.062 2,3 2 5	0.043 3 3 5	-.484 $p < 0.005$ (35)	
Registry Male (11)			0.014 3 3 11	0.041 3 2 11	0.080 2 2 11	0.144 1 1 11	0.109 1,2 1 11	0.089 2,3 2 11	0.072 2 2 11	-.443 $p < 0.001$ (77)	
Registry Female (1)			0.050 3 ---- 1	0.040 2 ---- 1	0.085 2 ---- 1	0.140 0 ---- 1	0.095 3 ---- 1	0.065 2 ---- 1	0.040 3 ---- 1	-.725 $p < 0.05$ (7)	
Total Registry (12)			0.017 3 3 12	0.041 3 2 12	0.080 2 2 12	0.144 1 1 12	0.108 1,2 1.5 12	0.087 2 2 12	0.069 2 2 12	(84)	
Total Social (20)			0.002 3 3 20	0.033 3 2.5 20	0.079 3 2 20	0.106 0,2 1 20	0.082 3 3 20	0.061 3 2.5 20	0.042 3 3 20	(140)	
Total (32)			0.007 3 3 32	0.036 3 2 32	0.080 2 2 32	0.120 0,1 1 32	0.092 3 2.5 32	0.071 3 2 32	0.052 3 3 32	-.422 $p < 0.05$ (224)	

correlation coefficients of BAQ by performance are shown for the number of pairs of data points, along with their level of significance, for each group of drinking subjects. Training schedule and the motivation scheme used during testing are also listed.

No control subjects were tested on this device, but a substantial number of registry subjects were run. Subjects were thus compared in the following manner: male vs. female registry subjects; male vs. female social subjects; and registry vs. social subjects. Since the data were nonparametic, no analyses were done.

Figure A-29 shows the median number of passes out of three possible passes for the 11 male and the one female registry drinking subjects as a function of testing conditions. Figure A-30 shows the same performance data for the 15 male and five female social drinking subjects.

Figure A-31 presents the scatterplot of the mean number of errors for all drinking subjects as a function of BAQ. The coefficient correlation is r_T $(N=222)=0.393$, $p < 0.005$.

A-2.3.8 <u>QuicKey</u>

A-2.3.8.1 <u>Description of Subjects' Task on the Device</u> - Developed by Robert D. Smith[7], this unit requires the operator to provide a simple-reaction response to visual stimuli. The operator's task is to depress a microswitch, and, as soon as a small light adjacent to the button flashes, to pull his finger away as quickly as possible. The method of determining the pass/fail criterion is somewhat different from that for the other devices. A characterisitic response latency (the reaction time in milliseconds between the light display and the release of the button) for each operator is determined from the eighth fastest response out of that operator's last 50 practice repetitions. This response latency is used as the upper limit of a passing band, with 85% of that value as the lower limit. Responses whose times do not fall within this band result in failure.

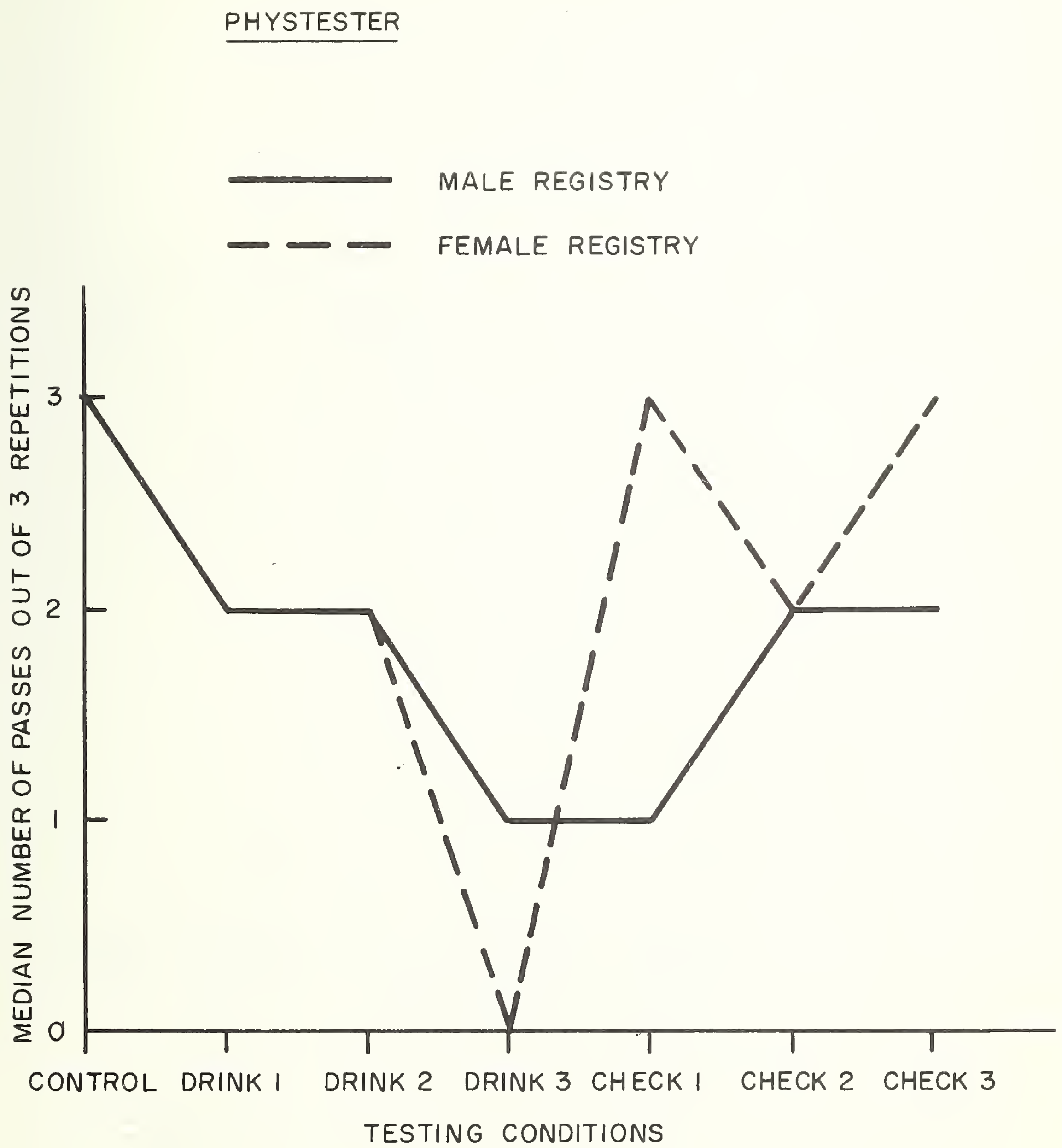

Figure A-29. Performance on the Phystester (in median number of passes out of three possible passes) for 11 Male and One Female Registry Drinking Subjects

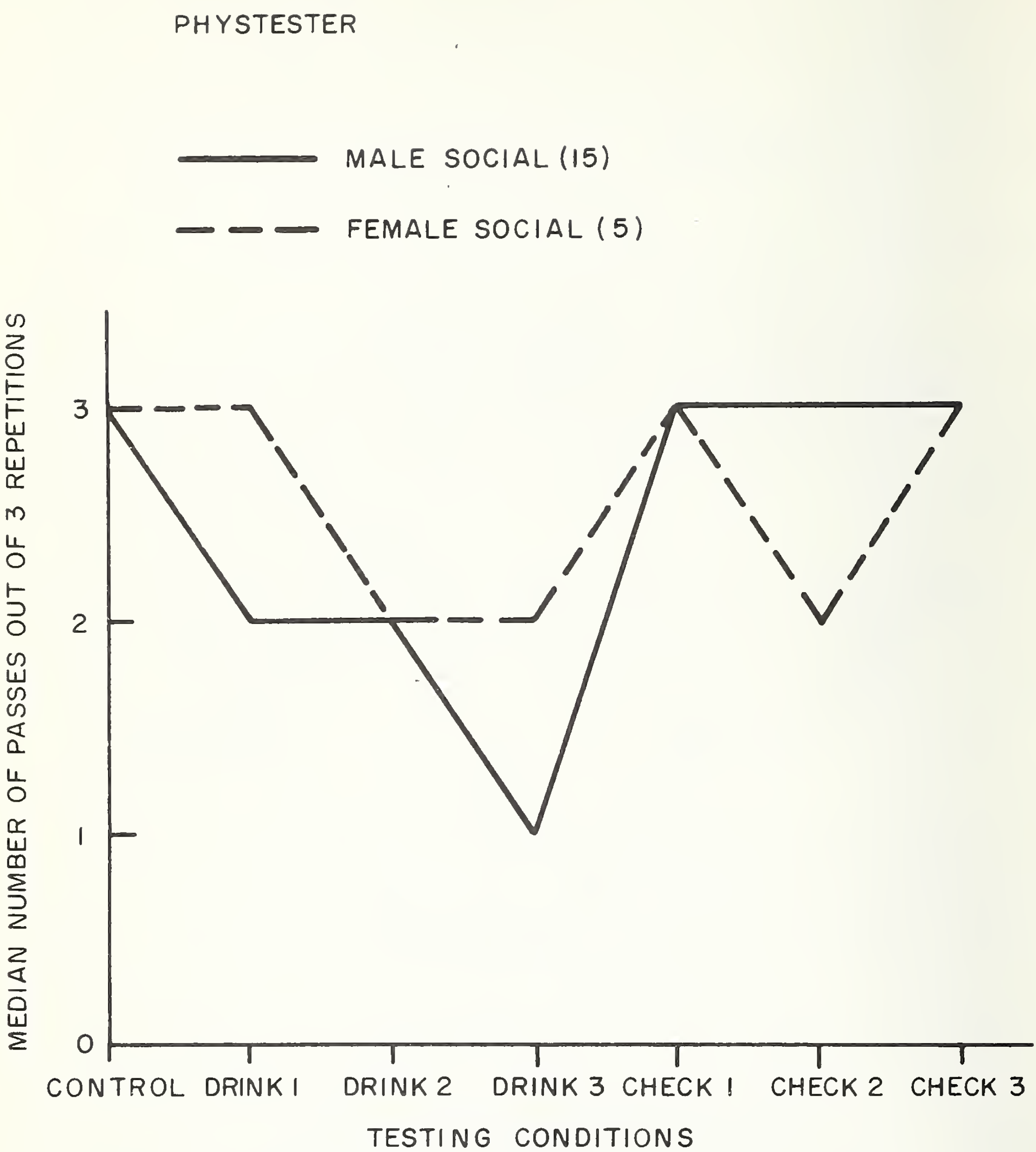

Figure A-30. Performance on the Phystester (in median number of passes out of three possible passes) for 15 Male and Five Female Social Drinking Subjects

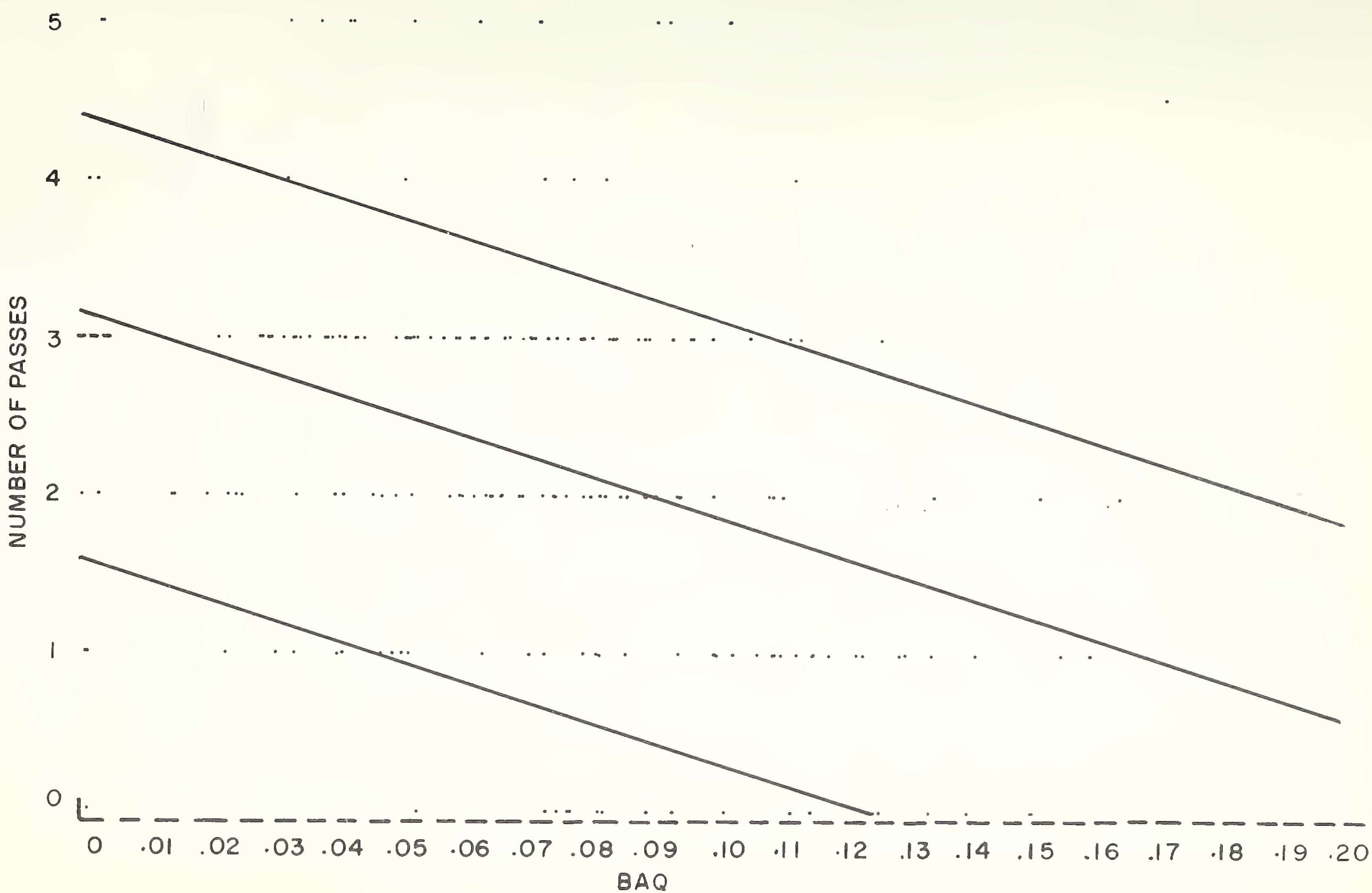

Figure A-31. Scatterplot of Number of Passes out of Three Trials on the Phystester Device against BAQ for all Drinking Subjects, and Regression Line with Brackets Enclosing 80% of the Points

A-2.3.8.2 <u>Results</u> - Subjects completed 30 repetitions within each of the seven testing conditions. Table A-30 lists the results as mean BAQ attained, mean time to complete the task, standard deviation, and number of data points per cell. The correlation coefficients of BAQ by performance were shown, along with the number of pairs and level of signigicance, for each group of drinking subjects. The training schedule and motivation scheme used during testing are also listed.

Figure A-32 shows the mean reaction time in milliseconds for the six male social drinking subjects (no control subjects were tested) as a function of testing condition. A summary of the analysis of variance is presented in Table A-31. This analysis shows that only the testing conditions ($F(6,30)=4.67$, $p < 0.001$) and not the repetitions within each trial ($F(29,145)=1.31$, $p > 0.05$), was statistically significant. The Tukey WSD test showed that the mean of the six male social drinking subjects' performance in the drink-3 condition was significantly worse ($p < 0.05$) than those for all other conditions.

Figure A-33 shows the mean reaction time in milliseconds for the four female social drinking subjects only (again there were no controls) as a function of testing condition. A summary of the analysis of variance is presented in Table A-32. This analysis shows only the testing conditions ($F(6,18)=128.74$, $p < 0.001$) and not the repetitions within each trial ($F(29,87)=1.22$, $p > 0.05$) to be a statistically significant effect. For the four female social drinking subjects, a Tukey WSD test showed that the means of the drink-3 and the check-1 conditions were significantly different from the other means, but not from each other.

Figure A-34 presents the scatterplot of the reaction times for all drinking subjects as a function of BAQ. The coefficient is r_T (N=2190)=0.343, $p < 0.001$).

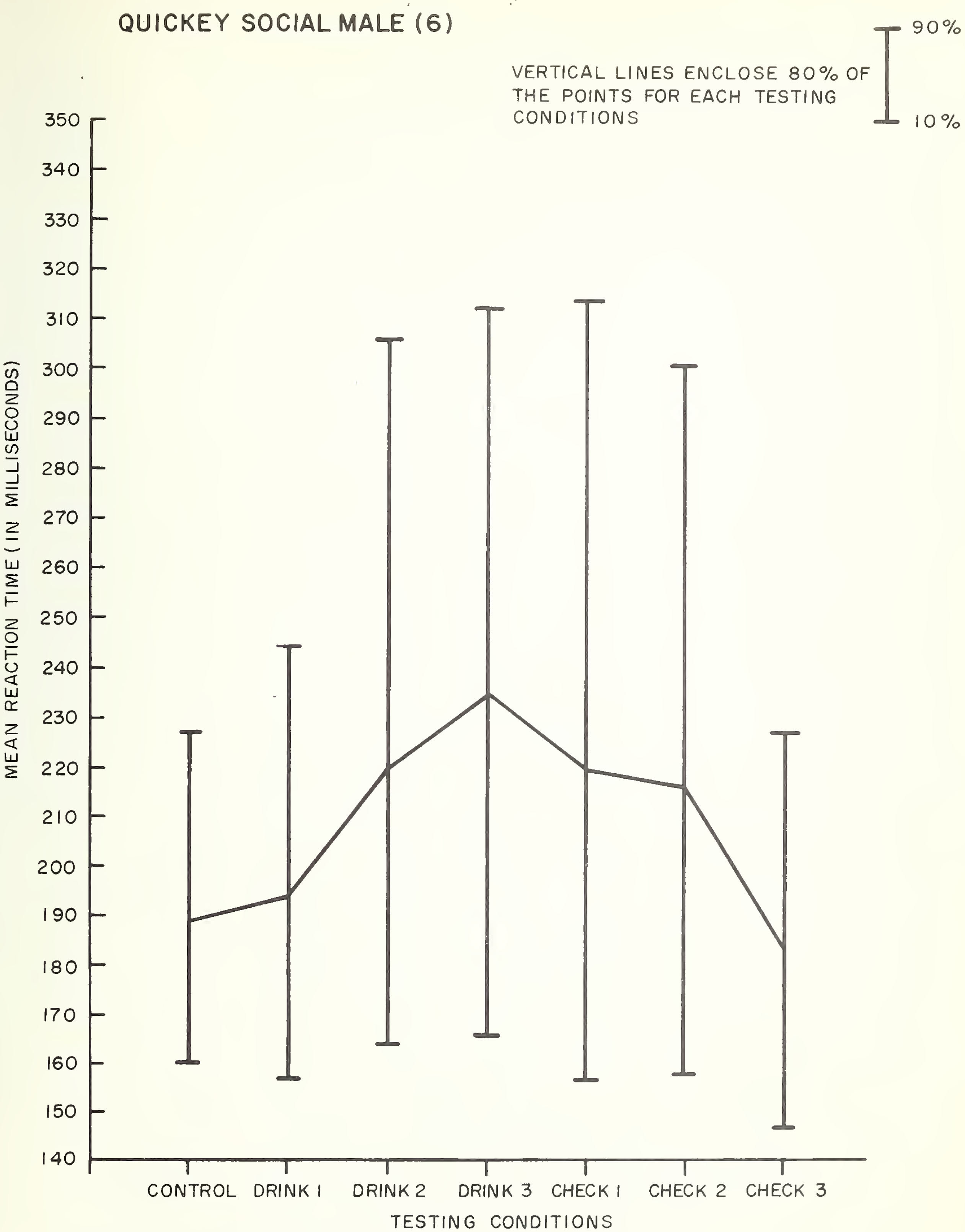

Figure A-32. Performance on the QuicKey Series as a Function of Testing Conditions for the Six Male Social Drinking Subjects

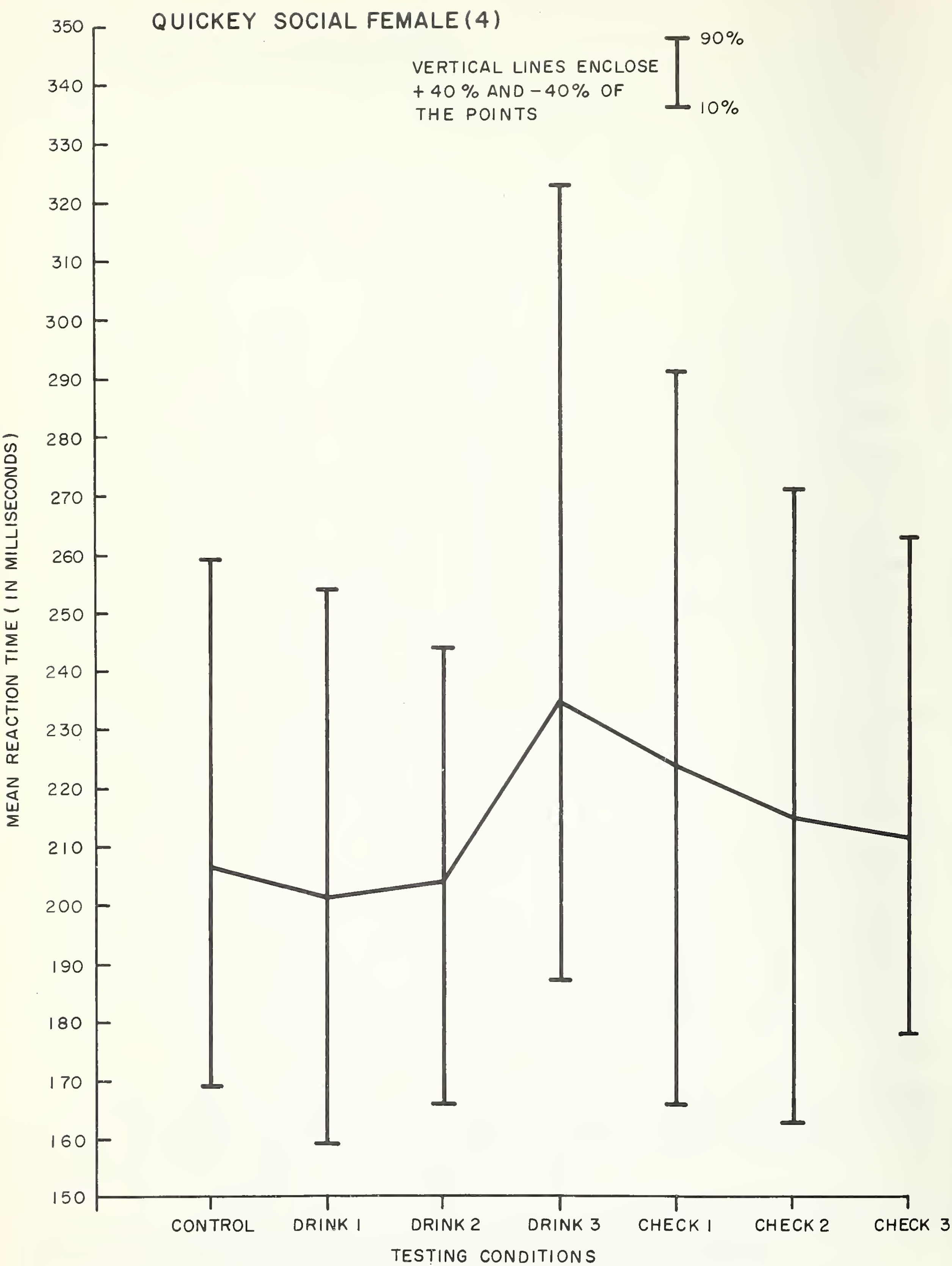

Figure A-33. Performance on the QuicKey Device as a Function of Testing Conditions for the Four Female Social Drinking Subjects

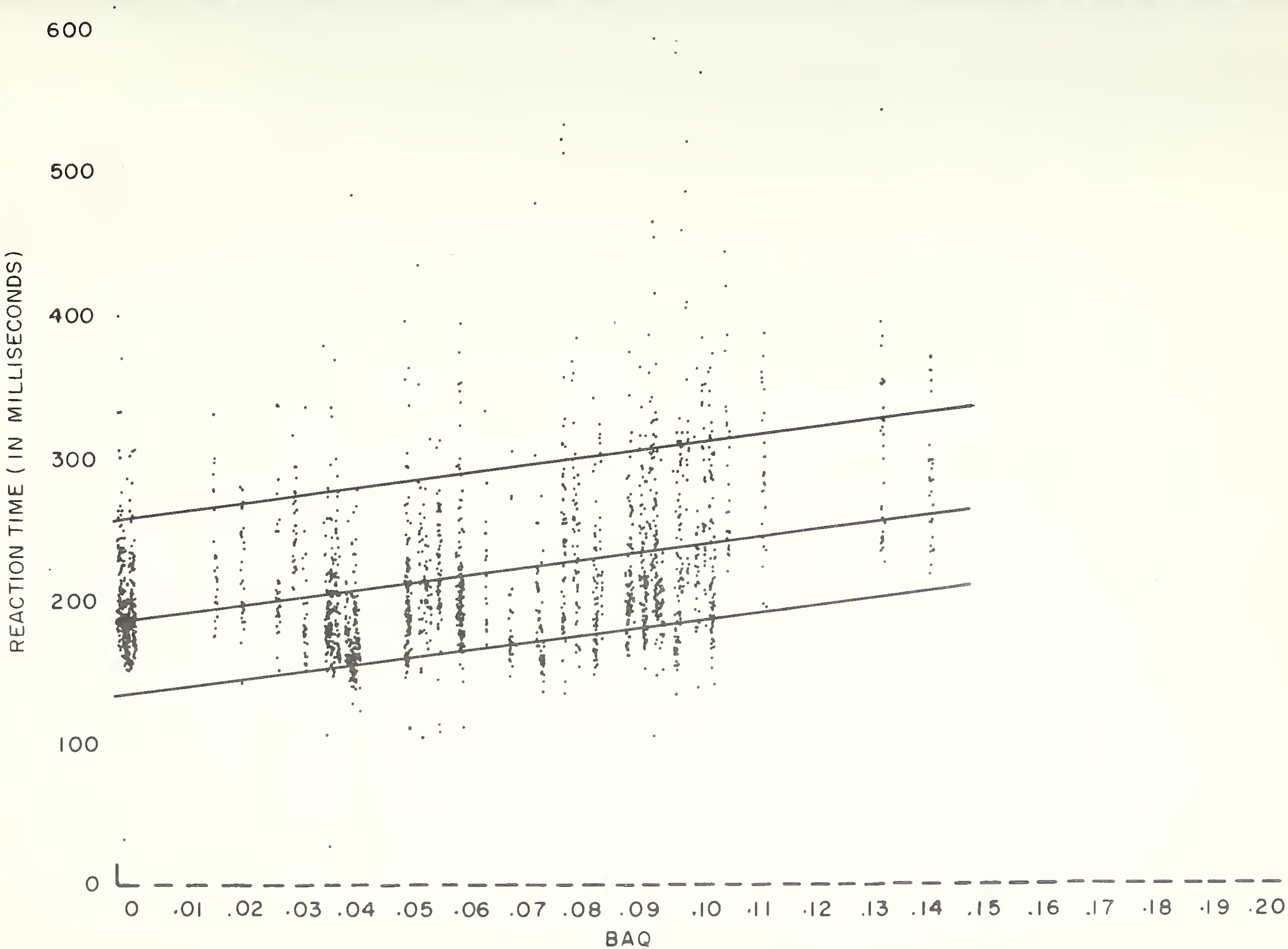

Figure A-34. Scatterplot of Reaction Times on the QuicKey device against BAQ for all Drinking Subjects, and Regression Line with Brackets Enclosing 80% of the Points

TABLE A-30. SUMMARY OF PERFORMANCE ON THE QUICKEY DEVICE

Robert D. Smith	DAY 1	DAY 2 - TESTING PERFORMANCE AS REACTION TIME (IN MILLISECONDS) (Ss performed 30 repetitions within each testing condition)								
Ss (#)	Training	Control	Drink 1	Drink 2	Drink 3	Check 1	Check 2	Check 3	Correlation BAQ X Perf.	Motivation (Bonus Money)
Social Male (6)	100 practice trials	0.000 189.42 36.12 180	0.039 193.50 36.12 180	0.088 219.93 57.24 180	0.088 235.85 73.07 180	0.083 220.76 67.15 180	0.072 216.79 65.47 180	0.050 183.30 36.40 120	0.390 P<0.001 (1200)	50¢ could be earned on each test trial if a score was not over 110% of the control condition score (within no lower limit)
Social Female (4)		0.004 205.89 34.95 120	0.030 201.52 42.18 120	0.069 202.18 43.93 120	0.080 231.00 67.88 90	0.077 225.61 50.20 90	0.052 216.73 50.86 90	0.030 211.72 47.85 60	0.131 P<0.01 (600)	
Registry Male (2)		0.000 213.54 35.75 60	0.040 228.44 32.86 60	0.095 236.95 41.92 60	0.140 284.33 44.74 30	0.110 277.67 45.65 30	0.100 277.83 45.30 30	0.080 274.57 42.39 30	0.440 P<0.001 (300)	
Total Registry (10)		0.002 196.01 36.50 300	0.034 196.71 38.79 300	0.080 212.83 52.97 300	0.085 234.23 71.29 270	0.081 222.38 61.96 270	0.064 216.77 60.89 270	0.042 192.77 42.61 180	0.306 P<0.001 (1890)	
Total Males (8)		0.000 195.45 37.45 240	0.039 202.24 38.39 240	0.090 224.19 54.24 240	0.101 242.78 71.69 210	0.090 228.89 67.45 210	0.079 225.51 66.44 210	0.058 201.55 52.44 150	0.405 P<0.001 (1500)	
Totals for Drinking Ss (12)		0.001 199.30 37.83 360	0.036 202.28 41.78 360	0.083 217.29 51.33 360	0.094 240.00 68.20 300	0.089 227.31 62.83 300	0.070 222.49 62.36 300	0.048 204.55 51.22 210	0.343 P<0.001 (2190)	

TABLE A-31. SUMMARY OF ANALYSIS OF VARIANCE FOR SIX MALE SOCIAL DRINKING SUBJECTS ON THE QUICKEY DEVICE

Source of Variance	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio
Total	1,115	4,126,368.0	3,700.78	
Repetitions (30)	29	91,872.0	3,168.00	1.31
Testing Conditions (7)	6	362,064.0	60,343.99	4.67*
Subjects (6)	5	1,076,768.0	215,353.56	
R x T	30	385,272.0	12,842.40	
R x S	145	351,192.0	2,422.01	
T x S	30	387,688.0	12,922.93	
R x T x S	870	1,471,512.0	1,691.39	

*p < 0.001

TABLE A-32. SUMMARY OF ANALYSIS OF VARIANCE FOR FOUR FEMALE SOCIAL DRINKING SUBJECTS ON THE QUICKEY DEVICE

Source of Variance	Degrees of Freedom	Sums of Squares	Mean Squares	F Ratio
Total	683	1,583,960.0	2,319.12	
Repetitions (30)	29	92,800.0	3,200.00	1.22
Testing Conditions (7)	6	88,060.0	14,676.66	128.77*
Subjects (4)	3	74,108.0	24,702.66	
R x T	18	355,568.0	19,753.77	
R x S	87	228,496.0	2,626.39	
T x S	18	2,052.0	114.00	
R x T x S	522	742,876.0	1,423.13	

*p < 0.001

A.2.4 SELECTION OF DEVICES FOR FUTURE TESTING

The instrument-screening tests had two objectives: first, to find out whether a performance-testing device could be used to construct an alcohol safety interlock system; and second, to find the performance-testing devices which would be most reasonable and practical for such a use. To fulfill the first requirement, it was necessary to determine how closely subjects' performance on the devices correlated with their BAQ's. It had to be demonstrated that performance fell and rose again as a function of testing condition (changes in BAQ level), and that this pattern was significantly different from that of the control subjects, who received no alcohol, but were subjected to the same laboratory testing routine. Such a difference should indicate that the changes in performance level over the testing session were due primarily to alcohol rather than to fatigue or boredom.

Fulfillment of the second requirement involved determining such things as the extent of training needed for someone to operate the device, the actual duration of the task, whether an universal pass/fail threshold could be set, and the cost and complexity of installing and maintaining the device in an automobile.

Table A-33 lists the devices screened and the coefficient of correlation between test performance and BAQ, together with the levels of significance for the effects of testing conditions and a comparison of the performances of drinking and control subjects. The existence of reasonable and statistically significant correlations on some of the devices showed that the ASIS idea is a feasible one, so those devices which seemed to best fulfill the second requirement were tested further.

The devices retained were: the Compensatory-Tracking Tester, the Complex-Reaction Tester, the Phystester, and QuicKey. Performance on the Compensatory-Tracking device correlated well with BAQ. Also, it was a cheaper, less complicated tracking device to use than the Pursuit-Tracking test. The Complex-Reaction Tester performed well only on the measure of number of errors made. However, since it was an early model of the device, it was retained

TABLE 33. RESULTS OF PRESCREENING ON THE BASIS OF QUANTITATIVE DATA

ASIS Device and No. of Subjects	Linear Correlation Coefficient (N)	Effect of Testing Conditions	Criticisms
Prototype Theft Lock (A.S. Dwan Ltd.) 25	0.156 (835) $p<0.05$	$p<0.01$ no discernible difference between drinking & control subjects	tremor
Critical Flicker-Fusion Tester (Creare Inc.) 29	0.107 (567) $p<0.05$	$p<0.01$ no discernible difference between drinking & control subjects	sensitive to ambient light, fatigue, illness. ± 1 Hz. too small a range.
Drunken-Driver Eliminator (TDL Group) 27	0.045 (2523) $p>0.05$	$p>0.05$ no discernible difference between drinking & control subjects	
Pursuit-Tracking Tester & Secondary Task (DOT-TSC) 32	0.392 (1140) $p<0.001$	$p<0.001$ no control subjects	expensive, complicated, individual.
Compensatory-Tracking Tester (DOT-TSC) 32	0.329 (1120) $p<0.01$	$p<0.01$ no control subjects	cheaper, simpler, individual considerable training.
Complex-Reaction Tester (DOT-TSC)			testing perceived as long and frustrating. Universal, little training, moderate cost.
Errors 18	0.153 (625) $p<0.01$	$p<0.01$ trend towards worsen performance for drinking subjects	
Same-Reaction 18	0.115 (625) $p<0.01$	$p<0.01$ no discernible difference	
Opposite-18 Reaction	0.046 (625) $p>0.05$	$p>0.05$ no discernible difference	
Phystester (General Motors) 32	0.393 (222) $p<0.005$	$p<0.005$ no control subjects	numbers - IQ. Universal, high cost, long training.
Quickey (R.D. Smith) 12	0.343 (2190) $p<0.001$	$p<0.001$ no control subjects	crucial training period for establishing individual criteria. Moderate cost.

for further testing. The correlation of performance with BAQ was highest with the Phystester. The only disadvantage of this device lies in the fact that it may eliminate some individuals who cannot readily manipulate numerical information. The QuicKey appeared to work well as an ASIS device and was retained for future testing. The primary disadvantage of this device is the long training period required to reach a stable criterion.

Both the Complex-Reaction Tester and the Phystester can best be described as universal ASIS; the QuicKey and Compensatory-Tracking Tester are individual devices.

The Prototype Theft Lock, the Creare device, Drunk-Driver Eliminator, and the Pursuit-Tracking device were dropped from further testing, primarily because the correlation of quantitative performance with BAQ on these devices was very low and, in some cases, not statistically significant. For these devices, it was also noted that there was little discernible difference between the performance of control and drinking subjects. The Prototype Theft Lock tended to artificially eliminate that portion of the population with some degree of tremor. The Creare had two basic disadvantages:

a. It is known that measures of flicker fusion are sensitive to variables other than alcohol, such as fatigue, ambient light, and illness.

b. The range of mean performance from the sober to the most intoxicated condition was about 2 Hz, too slight a difference for practical use.

The Drunk Driver Eliminator was the device whose performance correlated least with BAQ, and the only device for which testing conditions were not a significance effect. The performance (volt-seconds of tracking error) on the Pursuit-Tracking device did correlate well with BAQ, but it appeared too complicated and expensive a device to warrant further testing, especially as compared to the Compensatory-Tracking Tester. On the other hand, it did show the value of the addition of a secondary task, and thus is a good candidate for future quantitative performance testing of a divided-attention task.

A-3. PASS/FAIL EVALUATION

Further tests were made to determine the ability of the proposed ASIS units to discriminate between sober and intoxicated individuals. A pass/fail criterion was established for each of the four devices for which BAQ and performance were most closely correlated, so as to simulate an actual driving situation in which the operator's performance would determine whether he could start his car. The pass/fail tests were run in two series: Low-BAQ (up to .12% blood alcohol) and High-BAQ (up to .18% blood alcohol).

a. QuicKey - The procedure for establishing individual pass/fail cut-off points for this device was provided by the manufacturer. Each subject's eighth fastest score out of the last 50 training repetitions (the 16th percentile) served as his maximum allowable reaction time, and 85% of this value was defined as the minimum allowable response score.

b. Complex-Reaction Tester - Subjects were permitted no more than one error in eight presentations. Pressing the wrong button or responding in more than 0.9 seconds were considered errors.

c. Compensatory-Tracking Tester - The mean and the standard deviation of the scores on the last 36 training repetitions were calculated for each subject. Any score within the mean +1 standard deviation was passing; any score outside it was a failure.

d. Phystester - The pass/fail criterion for this device was suggested by the manufacturer. Subjects, after a five-digit number had been displayed for 1.5 seconds, had to complete the dual task of keying in the number and simultaneously pressing the brake pedal within 3.5 seconds in order to pass.

A.3.1 LOW-BAQ SERIES

A-3.1.1 Training

A three-day training period was employed. The amount of training done on each device is given in Table A-34. Details can be found in Volume II.

TABLE A-34. TRAINING SCHEDULE FOR PHASE THREE

Device	Number of Sessions/Day	No. of Repetitions Per Session	Total No. of Repetitions (3 days)
QuicKey	2	25	150
Phystester	8	25	600*
Compensatory Tracking Tester	6	6	108
Complex-Reaction Tester	4	4	48**

*Or until 23 passes out of 25 repetitions is reached.

**Gradually working subject towards criteria.

Subjects could earn bonus money up to $20 over and above base pay for being cooperative during training.

A-3.1.2 Testing

Subjects were tested on three separate days spaced two or three days apart. Testing procedures for each device are given in Table A-35.

A-3.1.3 Subject Selection

Nineteen subjects were trained and tested. Six female social, eleven male social, and two male registry subjects were tested with alcohol. Of these 19, six male social and two female social subjects were then tested without alcohol, i.e., the conditions under which they performed were identical except that the juice they drank contained no alcohol. Ages ranged from 21 to 28;

TABLE A-35. TESTING SCHEDULE FOR PHASE THREE

Device	Number of Repetitions/ Testing Condition	Payments/Passing Score
QuicKey	Maximum number possible in two minutes or until subject passed.	$1.50
Phystester	3	0.50
Compensatory-Tracking Tester	3	0.50
Complex-Reaction Tester	3	0.50

the mean age was 24.

A-3.1.4 Design

All drinking subjects performed on each device for each testing condition. Eight of these 19 subjects repeated the tests with no alcohol. This procedure not only permitted an evaluation of changes in performance as a function of testing conditions, but also screeened out any effects of extra-experimental variables, such as fatigue and boredom.

A-3.1.5 Results

The data were recorded in terms of pass or fail for each of three repetitions within each testing condition for the Compensatory-Tracking Tester, Complex-Reaction Tester, and Phystester, and as pass or fail only for the QuicKey. Consequently, a subject could score 0,1,2 or 3 passes for each testing condition on the first three devices, and 0 or 1 pass on the QuicKey. A variety of pass/fail criteria and number of trials could be used in an actual ASIS, but is was found that a criterion of at least two passes within three repetitions yielded the best start/no-start data, ie., few incorrect rejections at low BAQ's, and many correct rejections at higher BAQ levels. Table A-36 presents the percentage of no-starts as a function of BAQ classes for the devices in rank order.

TABLE A-36. PERCENTAGE OF NO-STARTS AS A FUNCTION OF BAQ CLASSES USING "AT LEAST TWO PASSES OUT OF THREE REPETITIONS" AS CRITERION*

BAQ Class	No. of Data Points	Compensatory-Tracking Tester	Complex Reaction Tester	Phystester	QuicKey
≤ 0.03	(118)	3.39%	8.47%	1.69%	4.24%
0.031-0.06	(119)	3.36	10.92	5.88	11.76
0.061-0.09	(100)	16.00	23.00	11.00	25.00
> 0.09	(62)	25.00	30.65	24.19	43.55
Difference between lowest and highest BAQ class		21.61	22.18	22.50	39.31

*Since QuicKey was scored the basis of a single trial, this criterion does not apply.

The graph in Figure A-35 shows the percentage of no-starts for each BAQ class. These classes were obtained by selecting BAQ intervals which would yield approximately equal numbers of data points

A Cochran Q test revealed that there was a significant difference among the devices when the data was collapsed across subjects, testing conditions, and testing days [Q(df=3) = 22.06, p < 0.001]. No statistical difference was found between the performances on the QuicKey device and the Complex-Reaction Tester [Q(df=1) = 0.49, 0.500< p < 0.250], or between the Compensatory-Tracking Tester and the Phystester [Q(df=1) = 0.60, 0.500 < p < 0.250; the difference appears between the Complex-Reaction Tester and the Compensatory-Tracking device [Q(df=1) = 7.12, 0.01 < p < 0.005].

The question of whether the increase in percentage of no-starts as BAQ class increases (as illustrated in Figure A-35) is a result of the effects of increased alcohol ingestion during the test program or is due to some other factor can be answered by comparing the performances of the same people when they are drinking

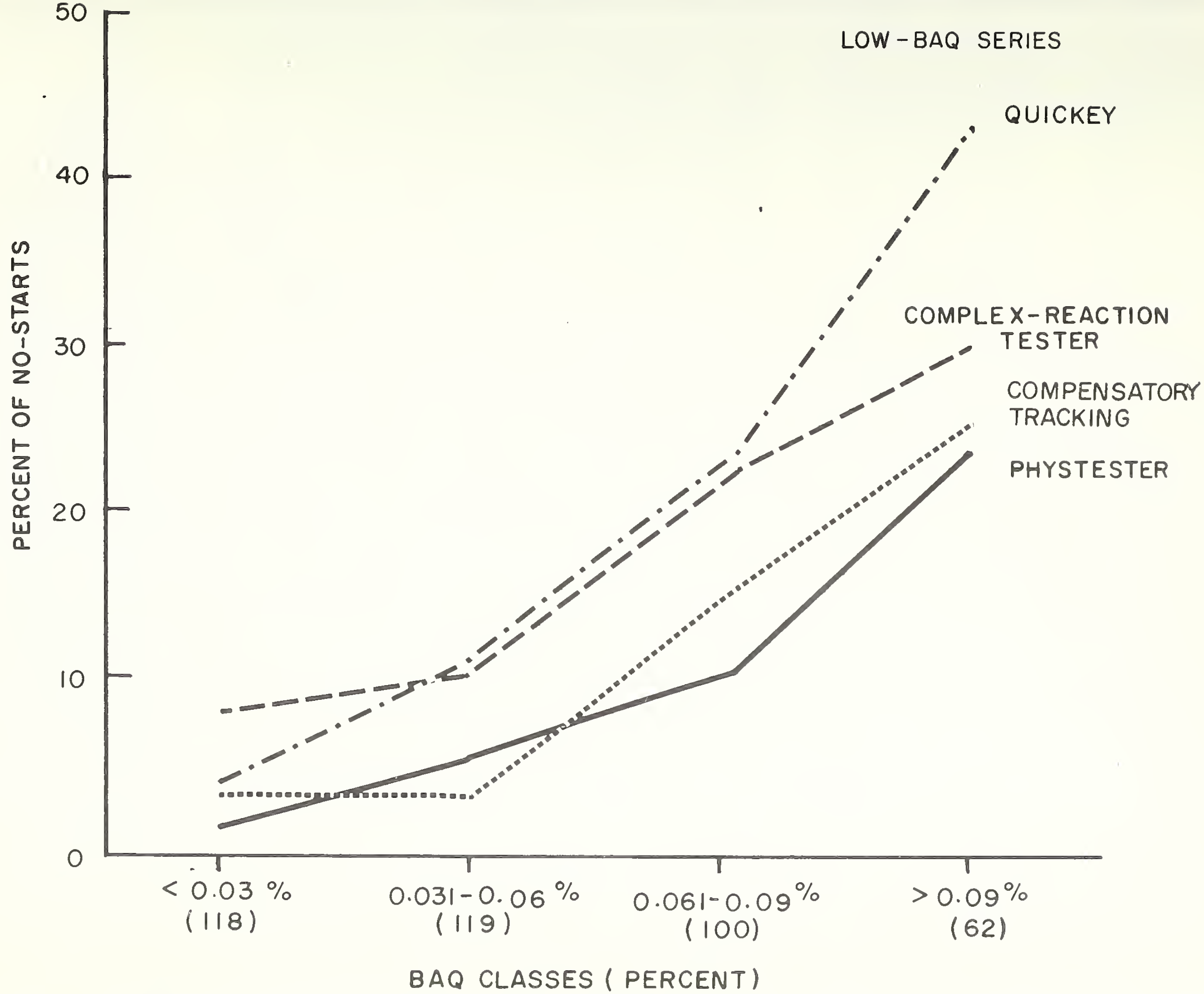

Figure A-35. Relation between BAQ and Percentage of No-Starts on Each Device Using "At Least Two Correct Responses"* as the Criterion for Starting.

*Since the QuicKey was scored on the basis of a single response this criterion does not apply.

subjects and when they are controls.

Table A-37 compares the percentage of no-starts for the "at least two correct to start" condition for each device over each of the seven testing conditions for the same subjects with and without alcohol (i.e., following the same schedule with no alcohol in their drinks).

Figures A-36 through A-39 present this comparison for each device. Note that the subjects failed to start less than 10% of the time. When given alcohol, these subjects also failed less than 10% of the time during the first testing condition, but their percentage of failure then rose and fell along with their rising and falling BAQ levels (see mean BAQ attained).

An analysis of variance was done on the data after an arc-sine transformation to determine the significance of these differences across the testing conditions. This analysis shows for the QuicKey device (see Table A-38) a significant difference between the same subjects when drinking and when not drinking ($F(1,7) = 10.93$, $p < 0.025$). A test of simple main effects reveals that this difference appears only for testing conditions 3 and 6. For the Complex-Reaction Tester (Table A-39), a significant difference also appears for testing conditions 3 and 5. For the Compensatory-Tracking Tester (Table A-40), no differences between drinking and not drinking testing conditions appeared until testing conditions 4 and 5. Finally, on the Phystester (Table A-41), a significant difference due to alcohol appeared, although only for testing condition 3.

Although these analyses are based on transformed start/no-start data on only eight subjects, the differences do show that the effects obtained were due predominantly to alcohol rather than to fatigue or boredom in a laboratory situation.

A-3.2 HIGH-BAQ SERIES

The Low-BAQ Series showed that performance on certain devices is related to the BAQ level of subjects. Pass/fail criteria were established for these devices (see Volume II), and subjects were

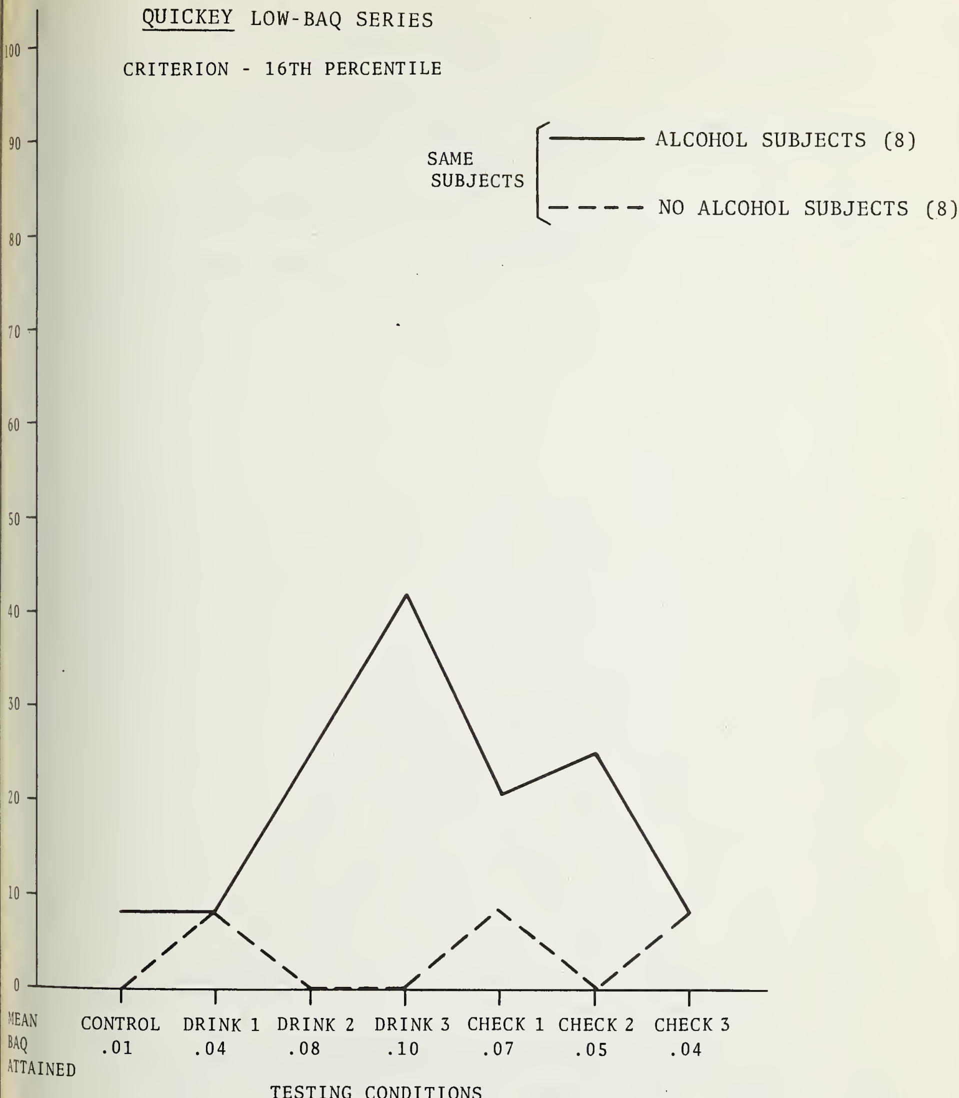

Figure A-36. Performance on the QuicKey as a Function of Testing Condition for the same Subjects Tested With and Without Alcohol

COMPLEX REACTION TESTER

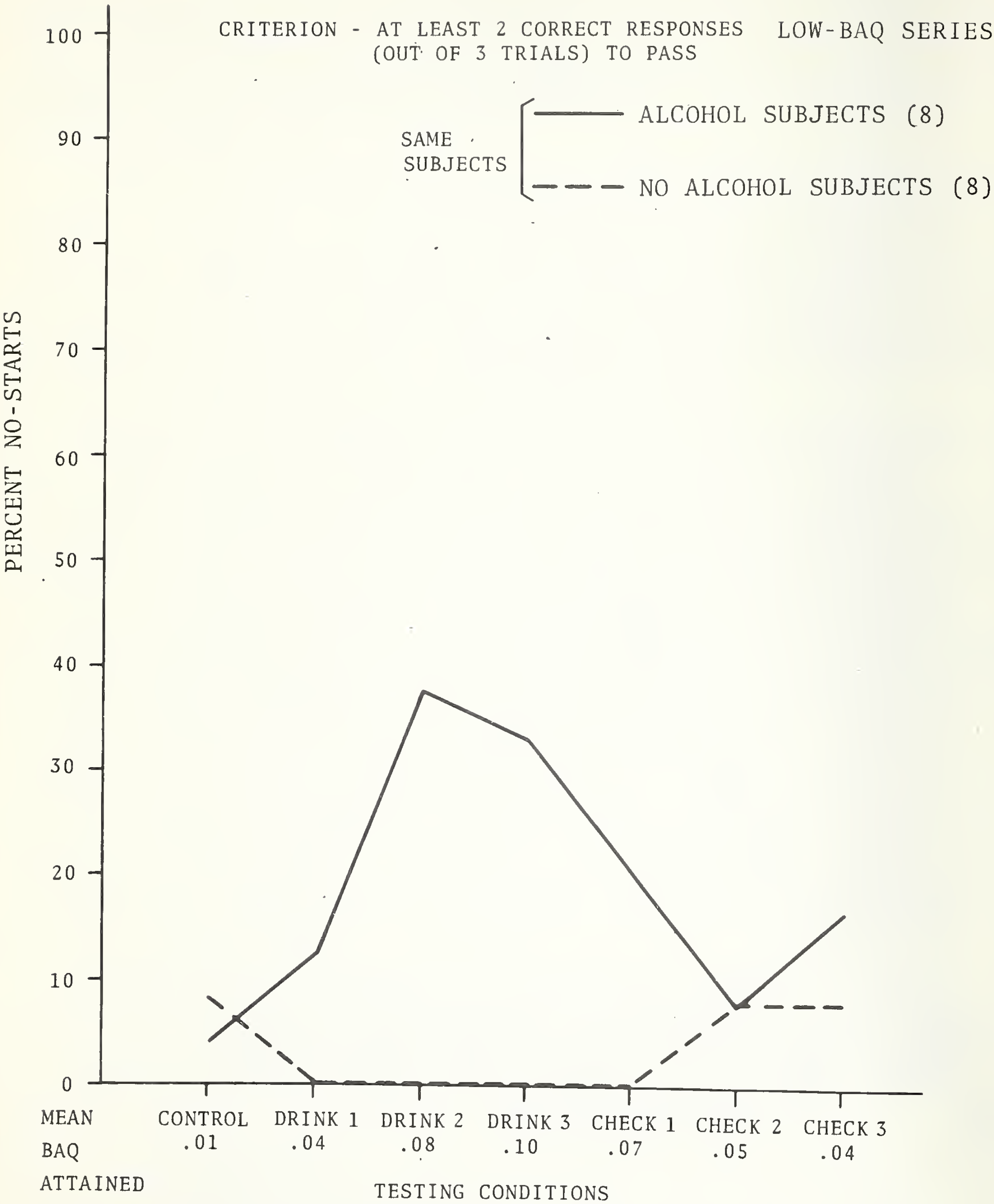

Figure A-37. Performance on the Complex-Reaction Tester as a Function of Testing Conditions for the Same Subjects Tested With and Without Alcohol

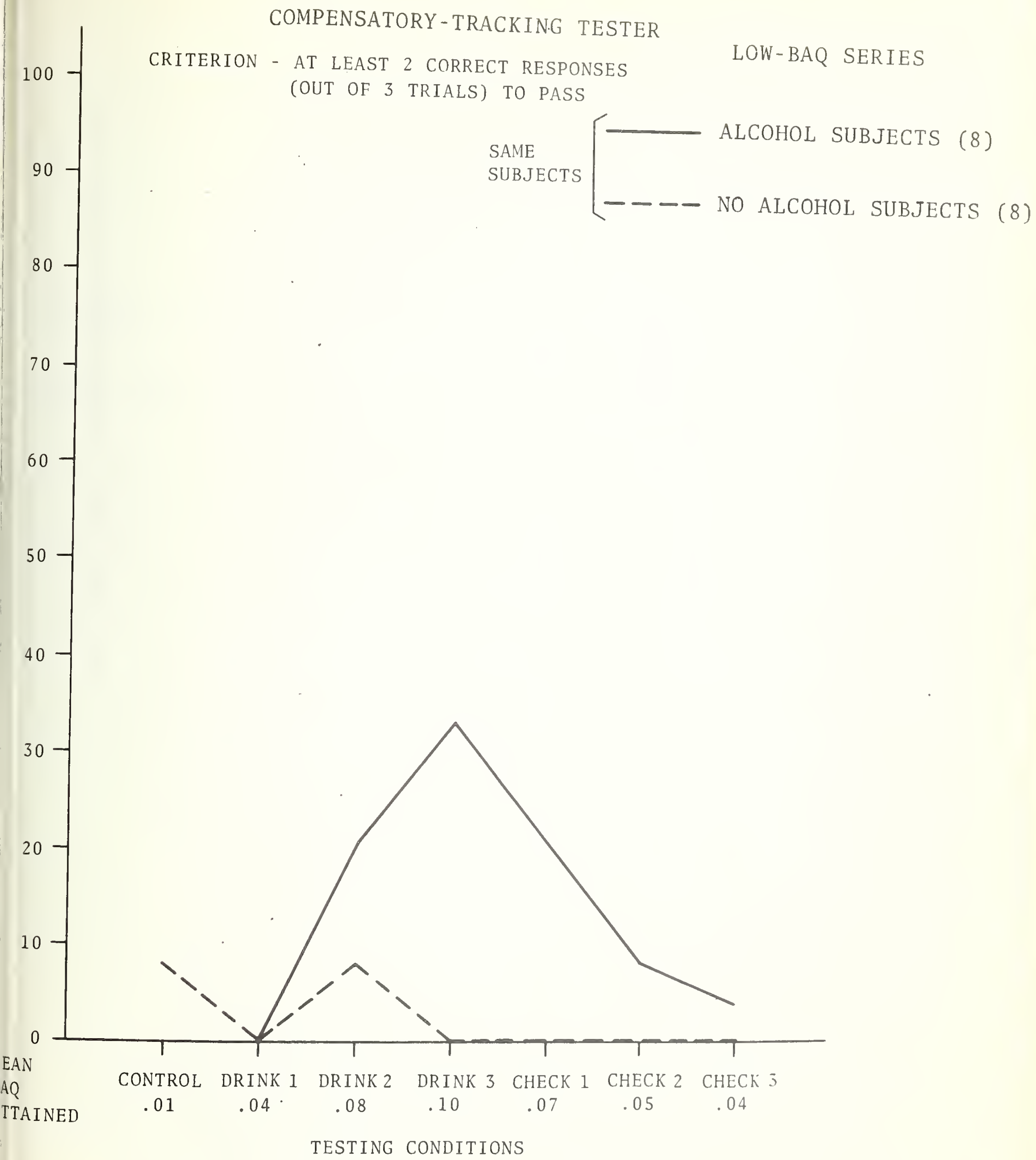

Figure A-38. Performance on the Compensatory-Tracking Tester as a Function of Testing Condition for the Same Subjects Tested With and Without Alcohol

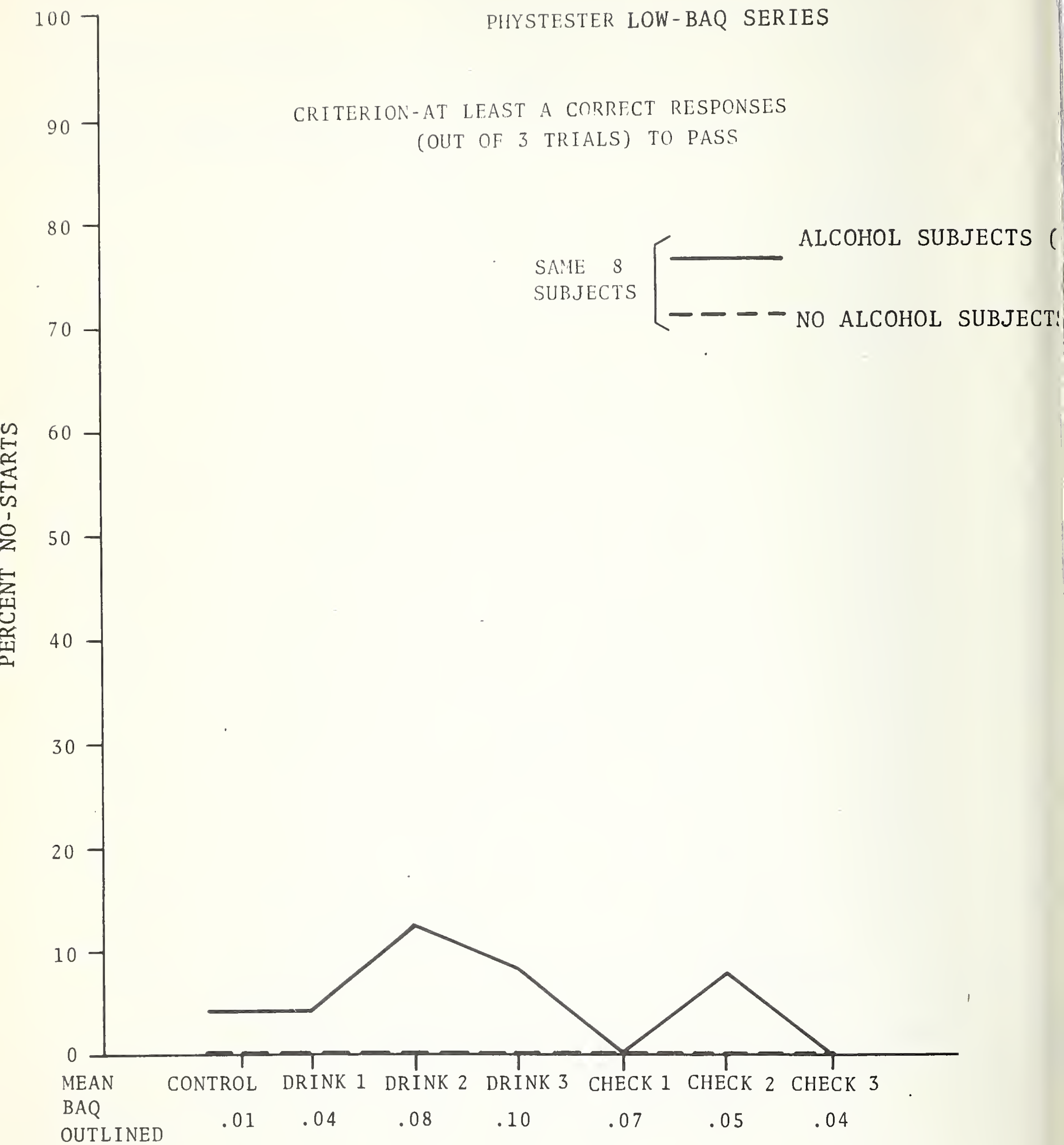

Figure A-39. Performance on the Phystester as a Function of Testing Condition for the Same Subjects Tested With and Without Alcohol

TABLE A-37. PERCENTAGE OF NO-STARTS FOR THE FOUR DEVICES AS A FUNCTION OF ALCOHOL AND TESTING CONDITIONS

	Testing Conditions						
	Control	Drink 1	Drink 2	Drink 3	Check 1	Check 2	Check 3
QuicKey							
Alcohol	8.3%	8.3%	25%	41.7%	20.8%	25%	8.3%
Juice Only	0.0	8.3	0:0	0.0	8.3	0.0	8.3
Complex-Reaction Tester							
Alcohol	4.2	12.5	37.5	33.3	20.8	8.3	16.7
Juice Only	8.3	0.0	0.0	0.0	0.0	8.3	8.3
Compensatory-Tracking Tester							
Alcohol	8.3	0.0	20.8	33.3	20.8	8.3	4.2
Juice Only	8.3	0.0	8.3	0.0	0.0	0.0	0.0
Phystester							
Alcohol	4.2	4.2	12.5	8.3	0.0	8.3	0.0
Juice Only	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE A-38. ANALYSIS-OF-VARIANCE SUMMARY

QuicKey (1 out of 1) - Low-BAQ Series					
Source of Variance	Degrees of Freedom	Sum of Squares	Mean Squares	F Ratio	Signi-ficance
Between Subjects	7	18.16	-	-	
Within Subjects	104	38.66	-	-	
Treatments	1	8.86	8.86	10.93	$p < 0.025$
Error	7	5.68	0.81	-	
Testing Conditions	6	2.90	0.48	3.01	$p < 0.025$
Error	42	6.74	0.16	-	
Interaction	6	5.08	0.85	3.78	$p < 0.01$
Error	42	9.41	0.22	-	
Total	111	56.82	-	-	

Difference due to alcohol at each testing condition					
Testing Condition	df	ss	ms	F Ratio	Signi-ficance
1	1	0.38	0.38	1.23	$p > 0.05$
2	1	0.01	0.01	0.23	$p > 0.05$
3	1	2.92	2.92	9.49	$p < 0.01$
4	1	7.10	7.10	23.06	$p < 0.01$
5	1	1.02	1.02	3.30	$p > 0.05$
6	1	2.47	2.47	8.02	$p < 0.01$
7	1	0.05	0.05	0.16	$p > 0.05$
Error	49	15.08	0.31	-	

TABLE A-39. ANALYSIS-OF-VARIANCE SUMMARY

Complex Reaction Tester (2 out of 3) - Low-BAO Series					
Source of Variance	Degrees of Freedom	Sum of Squares	Mean Squares	F Ratio	Significance
Between Subjects	7	14.64	-	-	
Within Subjects	104	40.54	-	-	
Treatments	1	8.48	8.48	8.39	$p < 0.025$
Error	7	7.08	1.01	-	
Testing Conditions	6	3.28	0.55	3.12	$p < 0.025$
Error	42	7.37	0.18	-	
Interaction	6	6.31	1.05	5.51	$p < 0.01$
Error	42	8.02	0.19	-	
Total	111	55.18	-	-	

Difference due to alcohol at each testing condition

Testing Conditions	df	ss	ms	F Ratio	Significance
1	1	0.01	0.01	0.02	$p > 0.05$
2	1	0.62	0.62	2.00	$p > 0.05$
3	1	6.93	6.93	22.49	$p < 0.01$
4	1	4.78	4.78	15.52	$p < 0.01$
5	1	1.96	1.96	6.37	$p < 0.025$
6	1	0.01	0.01	0.02	$p > 0.05$
7	1	0.49	0.49	1.59	$p > 0.05$
Error	49	15.09	15.09	-	

TABLE A-40. ANALYSIS-OF-VARIANCE SUMMARY

Compensatory-Tracking Tester (2 out of 3) - Low-BAQ Series					
Source of Variance	Degree of Freedom	Sum of Squares	Mean Squares	F Ratio	Significance
Between Subjects	7	9.16	-	-	
Within Subjects	104	35.78			
Treatments Error	1 7	4.49 6.39	4.49 0.91	4.92 -	$p > 0.05$
Testing Conditions Error	6 42	3.73 7.84	0.62 0.19	3.33 -	$p < 0.01$
Interaction Error	6 42	3.43 9.91	0.51 0.24	2.42 -	$p < 0.05$
Total	111	44.94	-	-	

Difference due to alcohol at each testing condition					
Testing Conditions	df	ss	ms	F Ratio	Significance
1	1	0.05	0.05	0.15	$p > 0.05$
2	1	0.00	0.00	0.00	$p > 0.05$
3	1	1.02	1.02	3.06	$p > 0.05$
4	1	4.78	4.78	14.37	$p < 0.01$
5	1	1.60	1.60	4.80	$p < 0.05$
6	1	0.38	0.38	1.14	$p > 0.05$
7	1	0.10	0.10	0.29	$p > 0.05$
Error	49	16.30	0.33	-	

TABLE A-41. ANALYSIS-OF VARIANCE SUMMARY

Physteester (2 out of 3) - Low-BAQ Series					
Source of Variance	Degrees of Freedom	Sum of Squares	Mean Squares	F Ratio	Significance
Between Subjects	7	0.80	-	-	
Within Subjects	104	12.47	-	-	
Treatments Error	1 7	0.99 0.80	0.99 0.11	8.68 -	$p < 0.025$
Testing Conditions Error	6 42	0.57 4.77	0.10 0.11	0.84 -	$p > 0.05$
Interaction Error	6 42	0.57 4.77	0.10 0.11	0.84 -	$p > 0.05$
Total	111	13.24	-	-	

Difference due to alcohol of each testing condition					
Testing Condition	df	ss	ms	F Ratio	Significance
1	1	0.10	0.10	0.83	$p > 0.05$
2	1	0.10	0.10	0.83	$p > 0.05$
3	1	0.62	0.62	5.43	$p < 0.025$
4	1	0.38	0.38	3.34	$p > 0.05$
5	1	0.00	0.00	0.00	$p > 0.05$
6	1	0.38	0.38	3.34	$p > 0.05$
7	1	0.00	0.00	0.00	$p > 0.05$
Error	49	5.57	0.11	-	

tested at BAQ levels up to about 0.12. It was noted that as BAQ levels increased, so did failures for drinking subjects. Furthermore, by comparing the performance of subjects, it was established that the greater number of failures could be attributed to the ingestion of alcohol, and not merely to fatigue or boredom. Since the devices had been determined to be suitable as alcohol-related hurdle ASIS for BAQ's up to about 0.12, it was decided (a) to test these devices at increased BAQ levels up to about 0.20, and also (b) to look at difficulties with age, gender, training schedules, motivation levels, etc., which might arise in an actual ASIS program.

A-3.2.1 <u>Devices Tested</u>

The High-BAQ Series utilized the QuicKey, Complex-Reaction Tester, the Phystester, and a compensatory-tracking device more efficient and less expensive than the one formerly tested: the Reaction Analyzer, submitted by Raytheon Company.[9*]

A-3.2.1.1 <u>Procedure</u> - Subjects used for the experiments described below were all carefully selected on the basis of their frequency and quantity of alcohol use, as determined from a thorough personal interview. They were all licensed drivers, ranging from 21 through 63 years of age; approximately half were females, and all were Caucasian.

Training, testing, and motivation were similar to that described in Section A-3.1. Fifteen subjects were tested on all devices both with and without alcohol. Details can be found in Volume III.

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*Nartron Inc.[10], also submitted a new device which included a mental-arithmetic/reaction-time task. Subjects had to add the stimulus numbers (any combination of the digits 8,4,2, and 1) and depress the corresponding response button (0-15). The allowable response time ranged from 1.15 to 2.25 seconds. Pass/fail performance criteria were not specified. However, the device failed mechanically before sufficient data had been obtained, and it was returned to the manufacturer.

A-3.2.1.2 No-Start Strategies - It became evident during the Low-BAQ series that there were not only many alternate pass/fail criteria for each device, but also many start/no-start strategies. The first two studies reported in Volume III were designed to explore such alternatives in order to determine the optimal ones to use. In general, it was found that the pass/fail criteria used in the Low-BAQ series were the most effective; however, the data did indicate a need to choose better start/no-start strategies. The following discussion presents comparisons of various such criteria and strategies, and the choice of the optimal no-start strategies for each device.

a. QuicKey - For the QuicKey device, pass/fail criteria could be altered in two ways: (a) by readjusting the size of the allowable-response window and (b) by requiring more than one acceptable response in a given time period (2 minutes in this case) for the test. The graphs in Figures A-40 through A-42 show the relative percentages of a failures for all the different windows tried for three groups of subjects, as reported in Volume III. Note that the slope of the curve is essentially the same in all cases. In general, the optimal criterion in the present context appears to be the 16th-percentile one. Figures A-43 and A-44 compare performance using at least one or two 16th-percentile-criterion responses within two minutes. Here there is a trade-off problem, in that requiring at least two responses yields more rejections at high BAQ levels, but correspondingly higher rejection levels at very low BAQs as well. It was decided to continue with requiring one pass at the 16th-percentile window in two minutes for a start.

b. Complex-Reaction Tester - Each trial on this device consisted of three repetitions of the task. Figures A-45 and A-46 show (for groups 1 and 2, as reported in Volume III) the various possible pass/fail criteria which should be used for scoring performance: 2/3 (at least 2 passes out of 3 trials), 3/3, 2/2, and 1/1. Again, note the high rejection rates at low BAQ levels. It was decided to retain the 2/3 criterion.

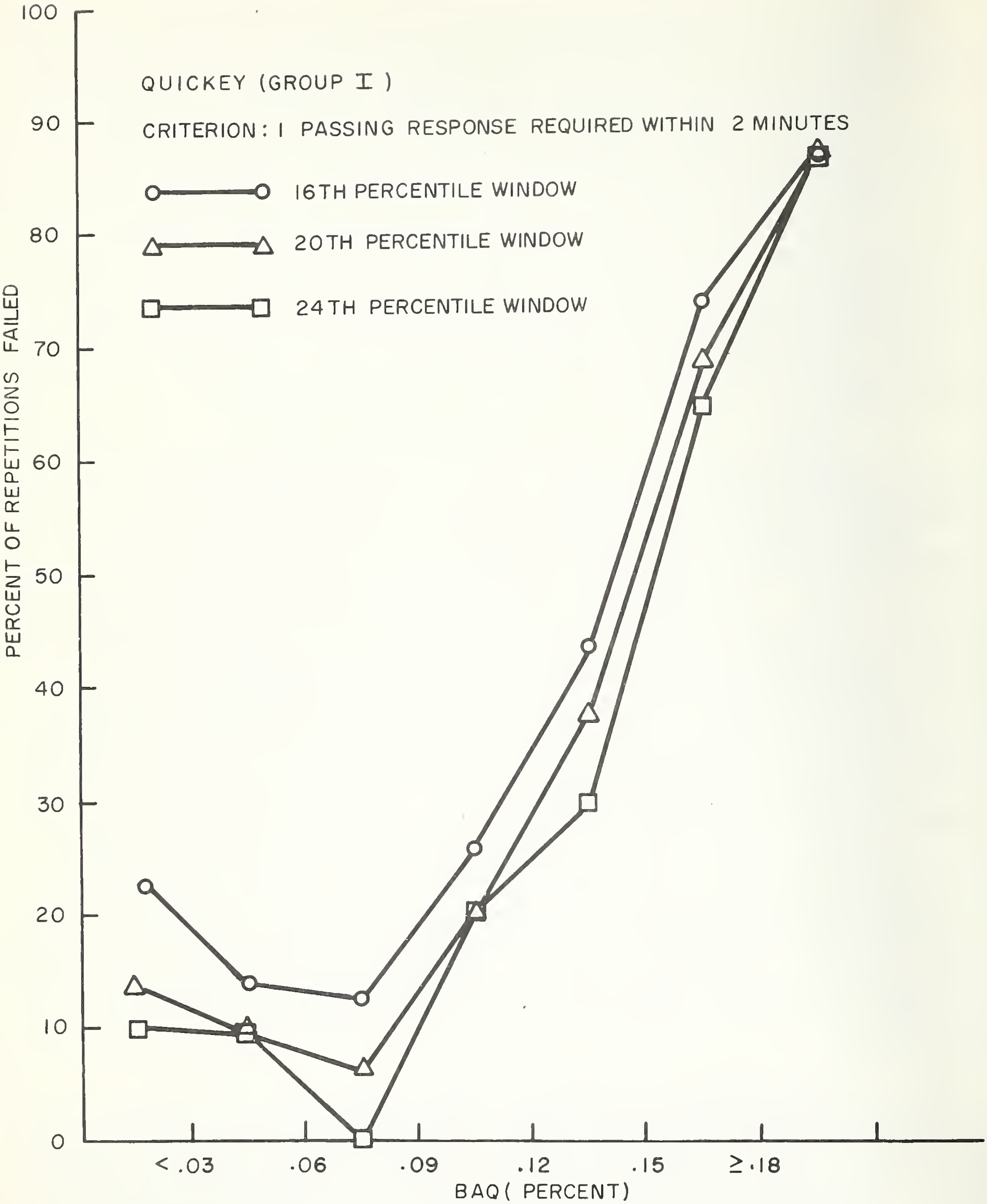

Figure A-40. Pass/Fail Performance on the QuicKey as a Function of BAQ, Using One Response at the 16th, 20th, and 24th Percentile as Criterion

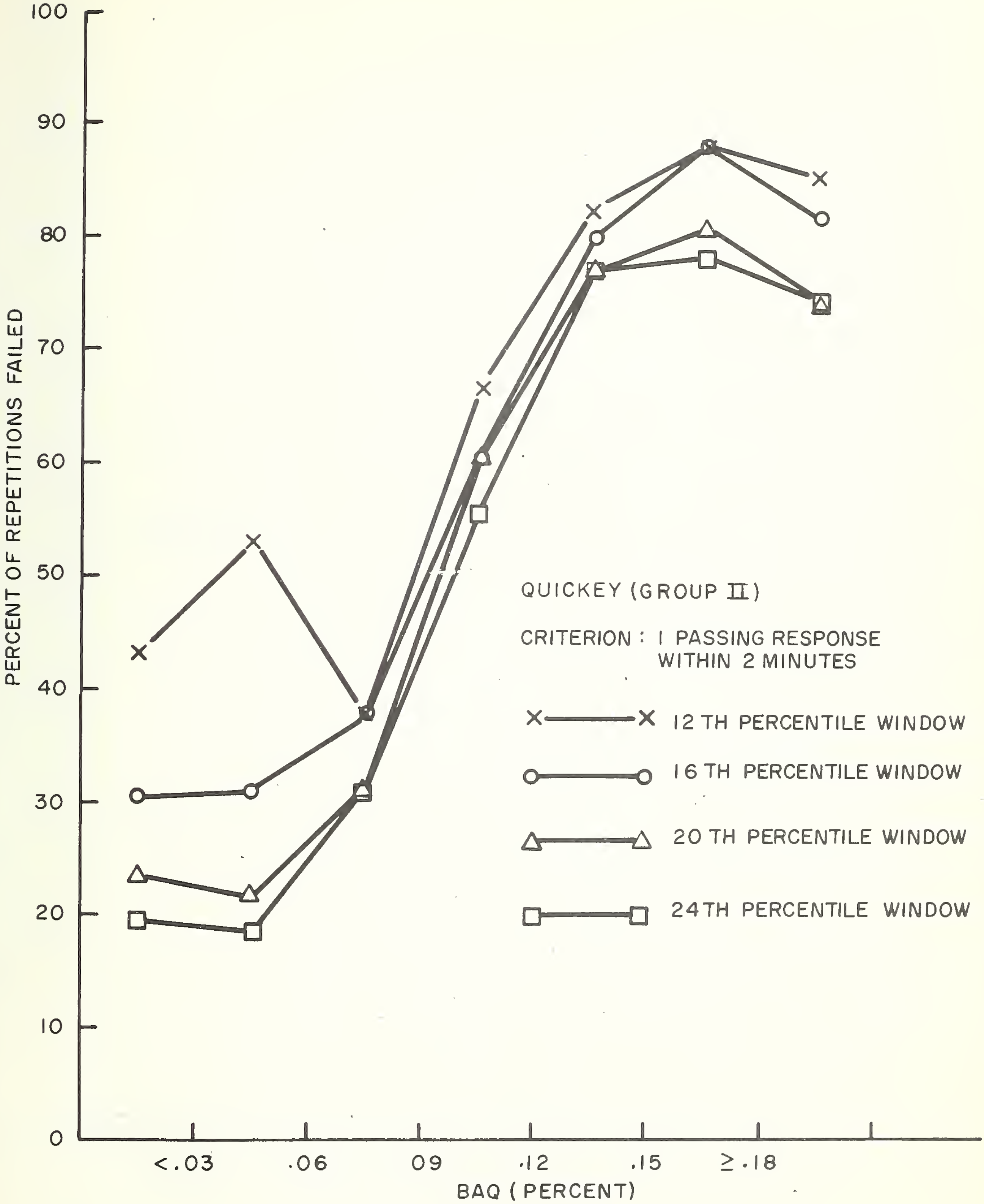

Figure A-41. Pass/Fail Performance on the QuicKey as a Function of BAQ, Using One Response at the 12th, 16th, 20th, and 24th Percentile as Criterion

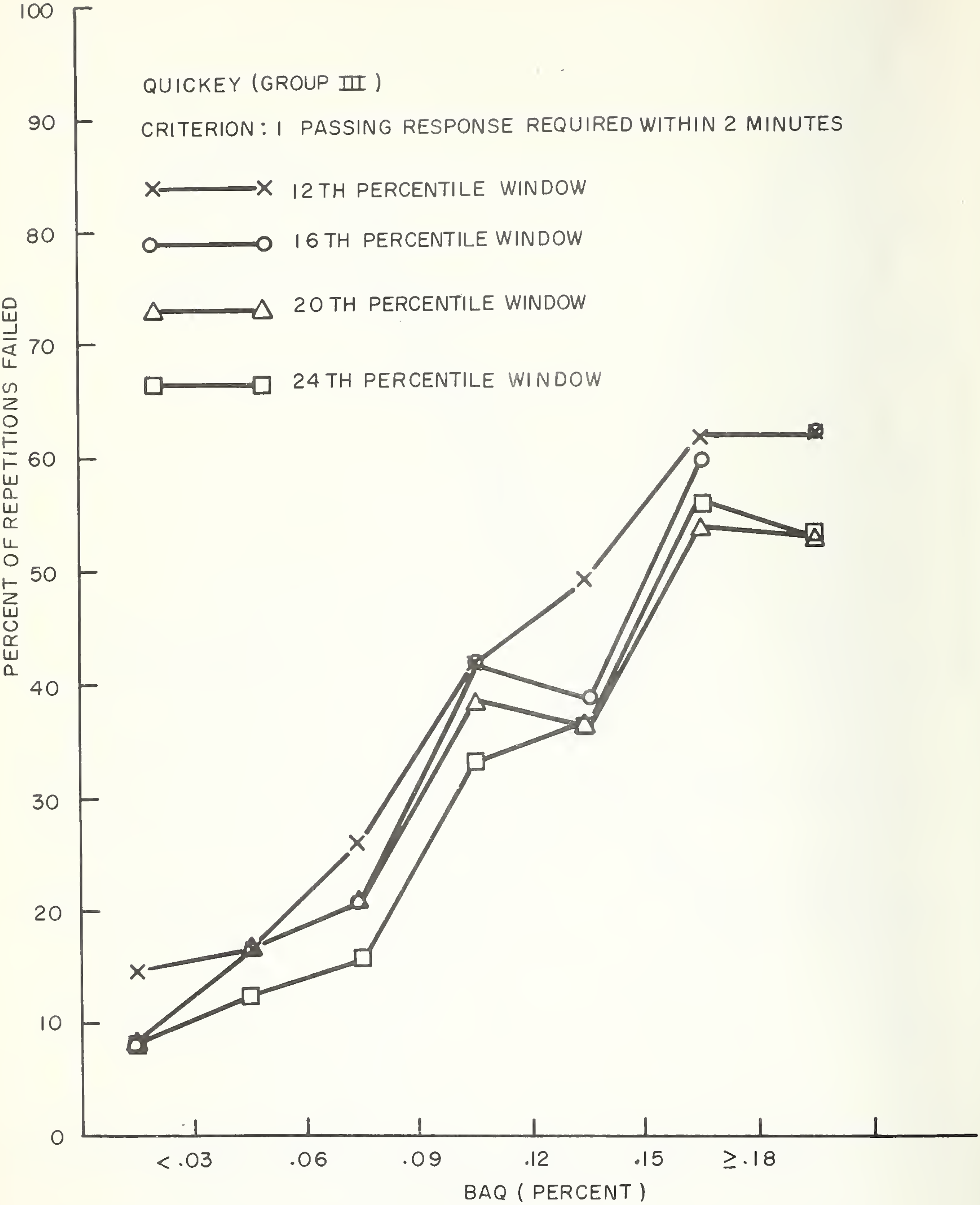

Figure A-42. Pass/Fail Performance on the QuicKey as a Function of BAQ, Using One Response at the 12th, 16th, 20th, and 24th Percentile as Criterion

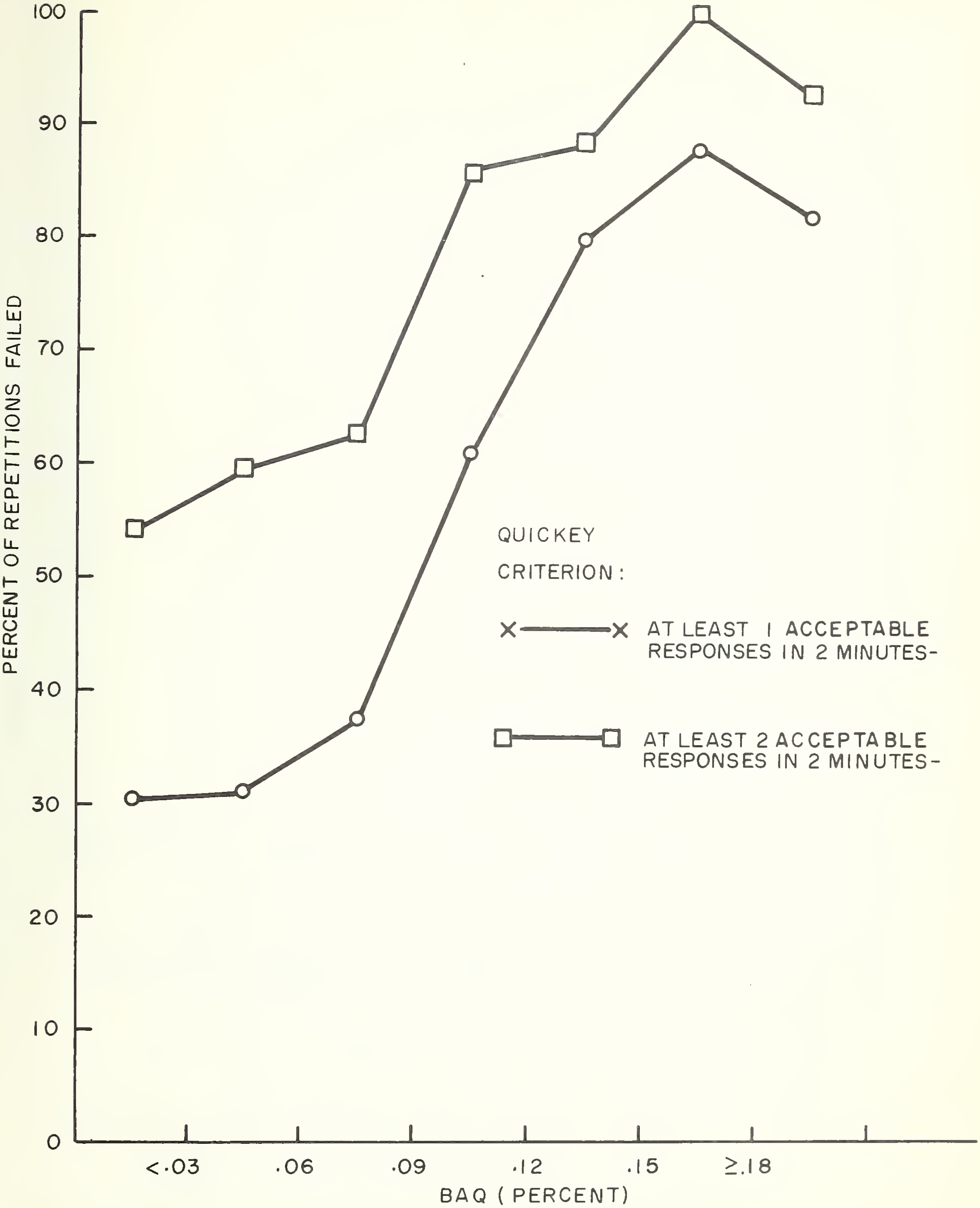

Figure A-43. Pass/Fail Performance on the QuicKey as a Function of BAQ, for One or Two Acceptable Responses at the 16th-Percentile Window

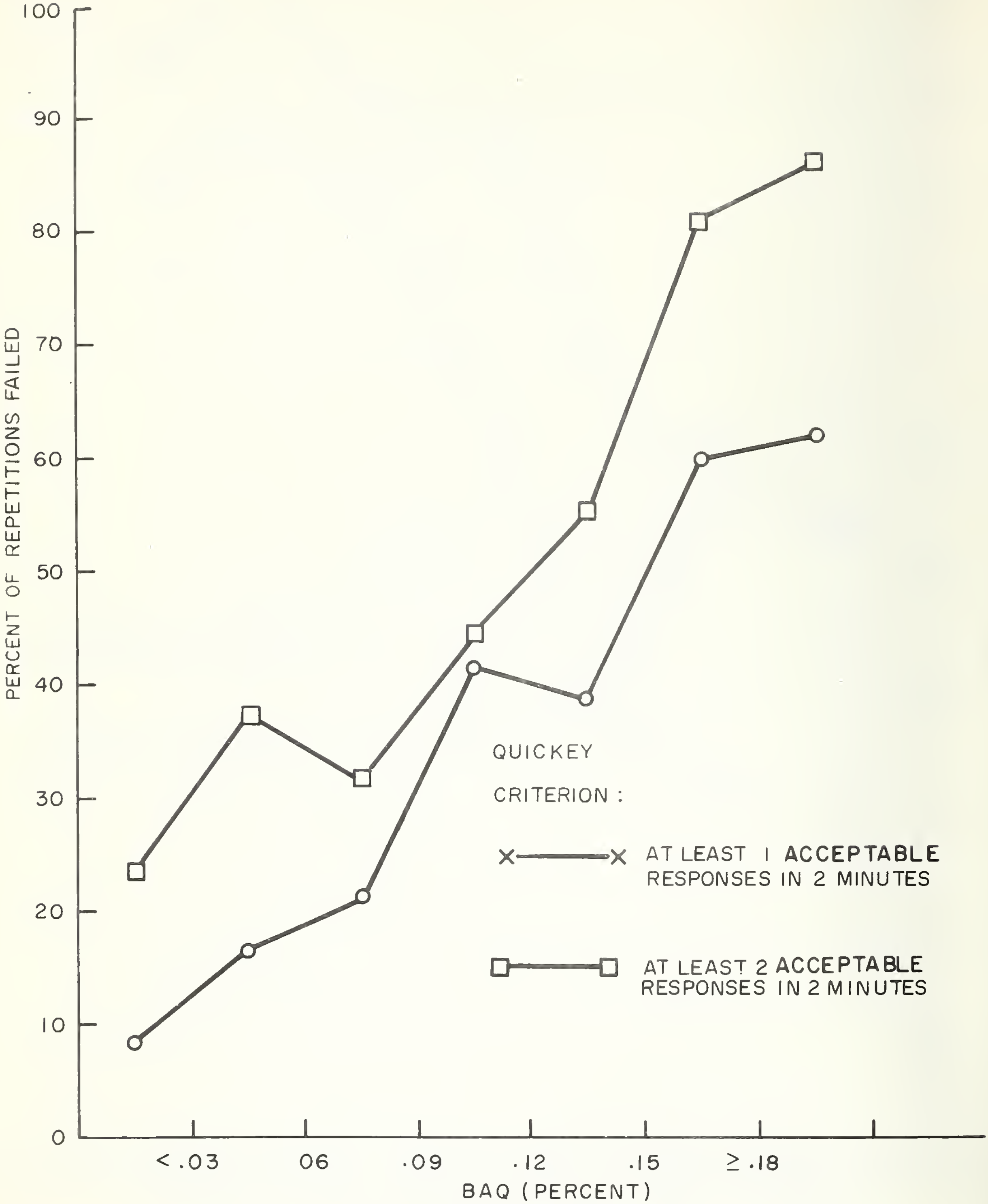

Figure A-44. Pass/Fail Performance on the QuicKey as a Function of BAQ, for One or Two Acceptable Responses at the 16th-Percentile Window

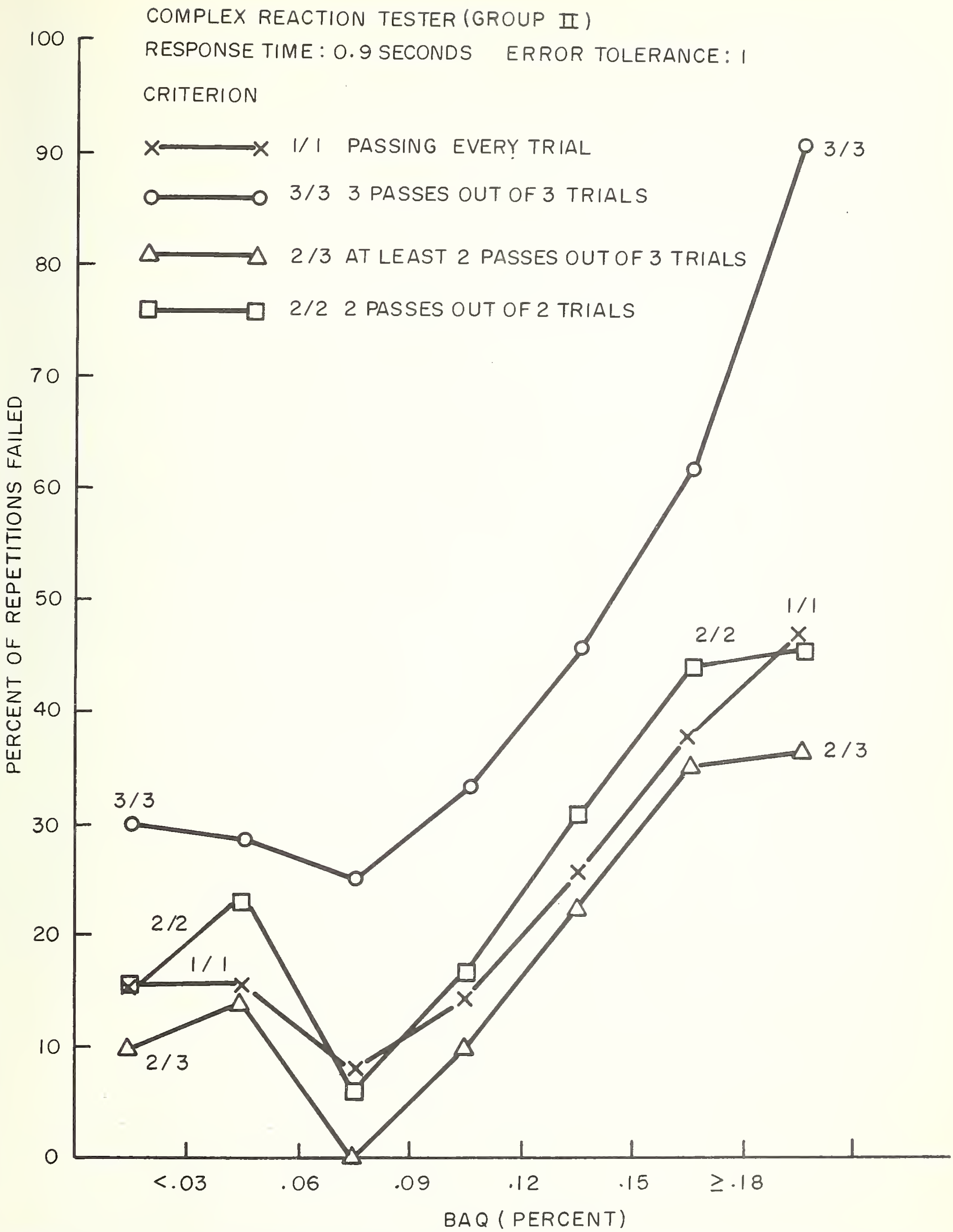

Figure A-45. Pass/Fail Performance on the Complex-Reaction Tester as a Function of BAQ, for Four Response Criteria

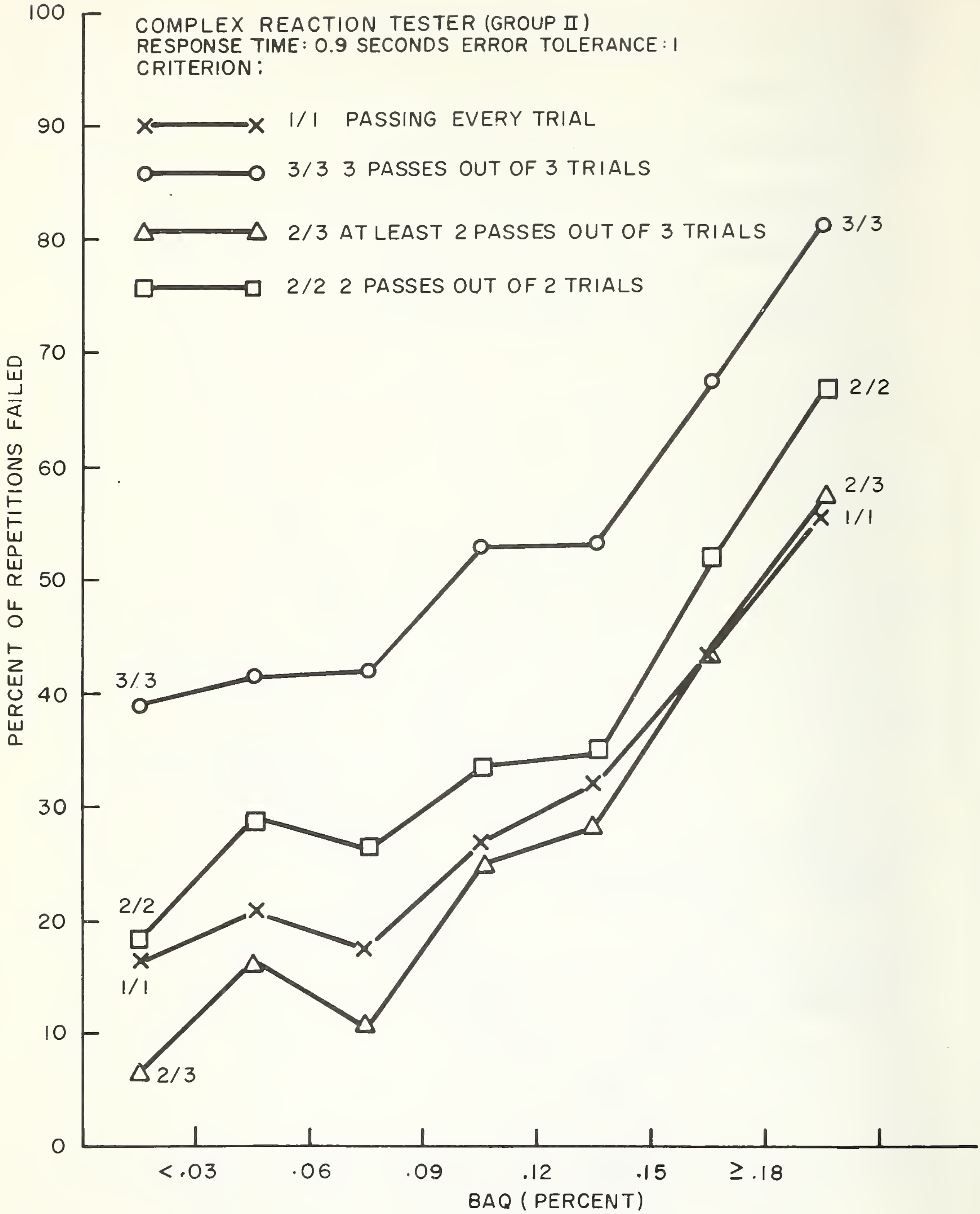

Figure A-46. Pass/Fail Performance on the Complex-Reaction Tester as a Function of BAQ, for Four Response Criteria

c. Reaction Analyzer - The Reaction Analyzer was introduced into the program late, and with no established pass/fail criterion. Subjects repeated the task five times for each trial. Results for the criterion employed (for groups 2 and 3, as reported in Volume III) are graphed in Figures A-47 and A-48. The 3/3 criterion appears to be optimal, especially for the third group, who were well trained. Note again the problem of correspondingly high rejection rates at high and low BAQ levels for each criterion.

d. Phystester - Although a two-out-of-three pass/fail criterion for the Phystester had been suggested by the manufacturer, several alternative criteria were investigated: 1/1, 3/3, and 2/2. Results are shown in Figures A-49 through A-51 (for groups 1, 2 and 3 as reported in Volume III). A second alteration in the pass/fail criterion was employed with Group 3; they had only 3.0 seconds to complete the task, rather than the 3.6 seconds previously allowed. The best criterion appears to be 2/3 for either response time. Note that the trade-off problem appears again.

A-3.2.2 Results for Devices

a. QuicKey - Results for the High-BAQ Series are presented in Table A-42. Data from the Low-BAQ Series are included for comparison; the percentages of no-starts as a function of BAQ for both groups of subjects are essentially the same for the BAQ ranges covered ($t(6)=0.17$, $p > 0.05$).

TABLE A-42. PERCENT OF NO-STARTS FOR THE 16TH-PERCENTILE "WINDOW" FOR THE QUICKEY DEVICE

BAQ Class	High-BAQ Series		Low-BAQ Series	
	%	Failures/Trials	%	Failure/ Trials
< 0.30%	8.5	(5/59)	4.24	(5/118)
0.030 - 0.059%	16.7	(4/24)	11.76	(14/119)
0.060 - 0.089%	21.1	(4/19)	25.00	(25/100)
0.090 - 0.119%	41.7	(15/36)	43.55	(27/62)
0.120 - 0.149%	38.8	(19/49)		
0.150 - 0.179%	59.6	(31/52)		
≥ 0.180%	61.9	(13/21)		

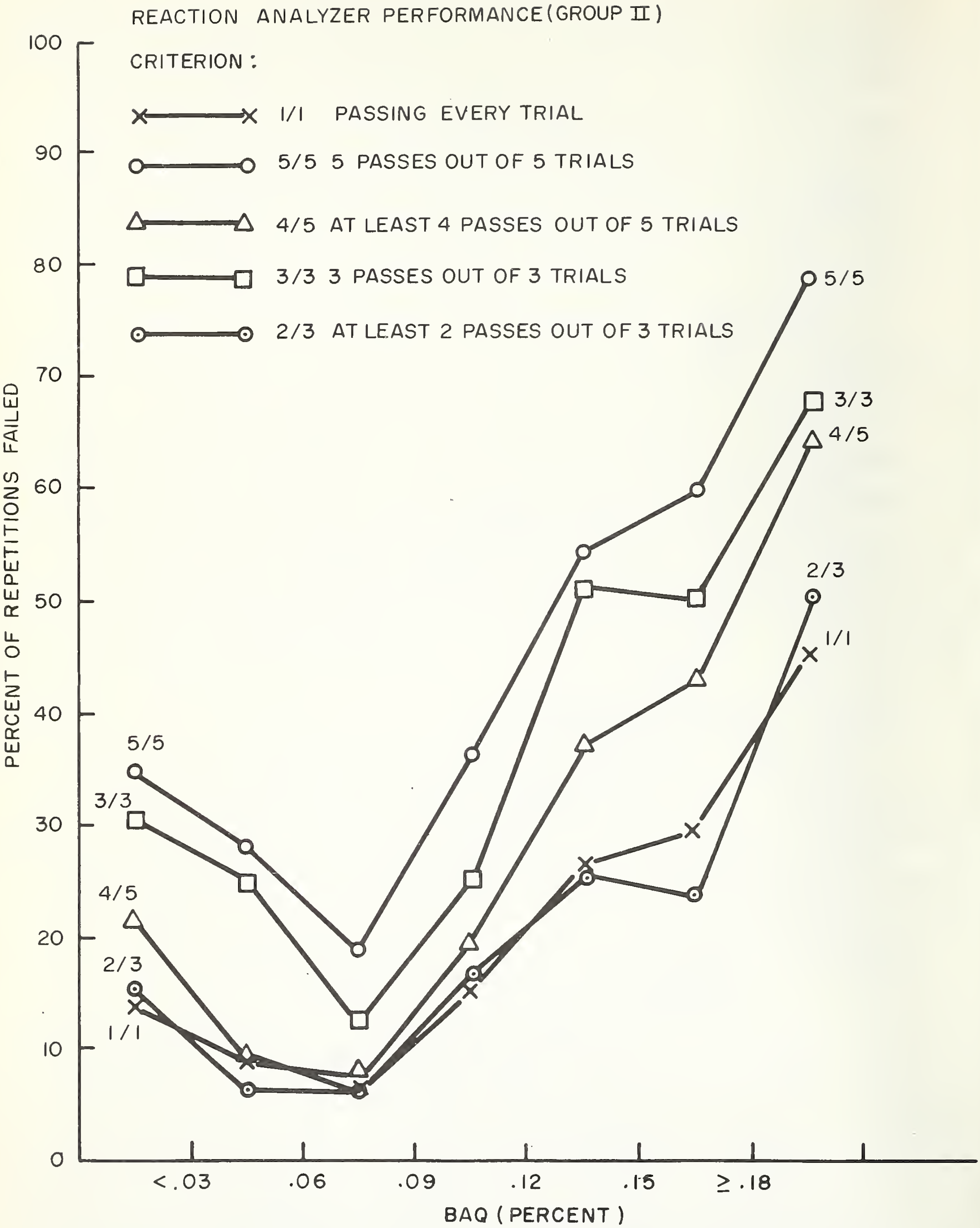

Figure A-47. Pass/Fail Performance on the Reaction Analyzer as a Function of BAQ, for Five Response Criteria

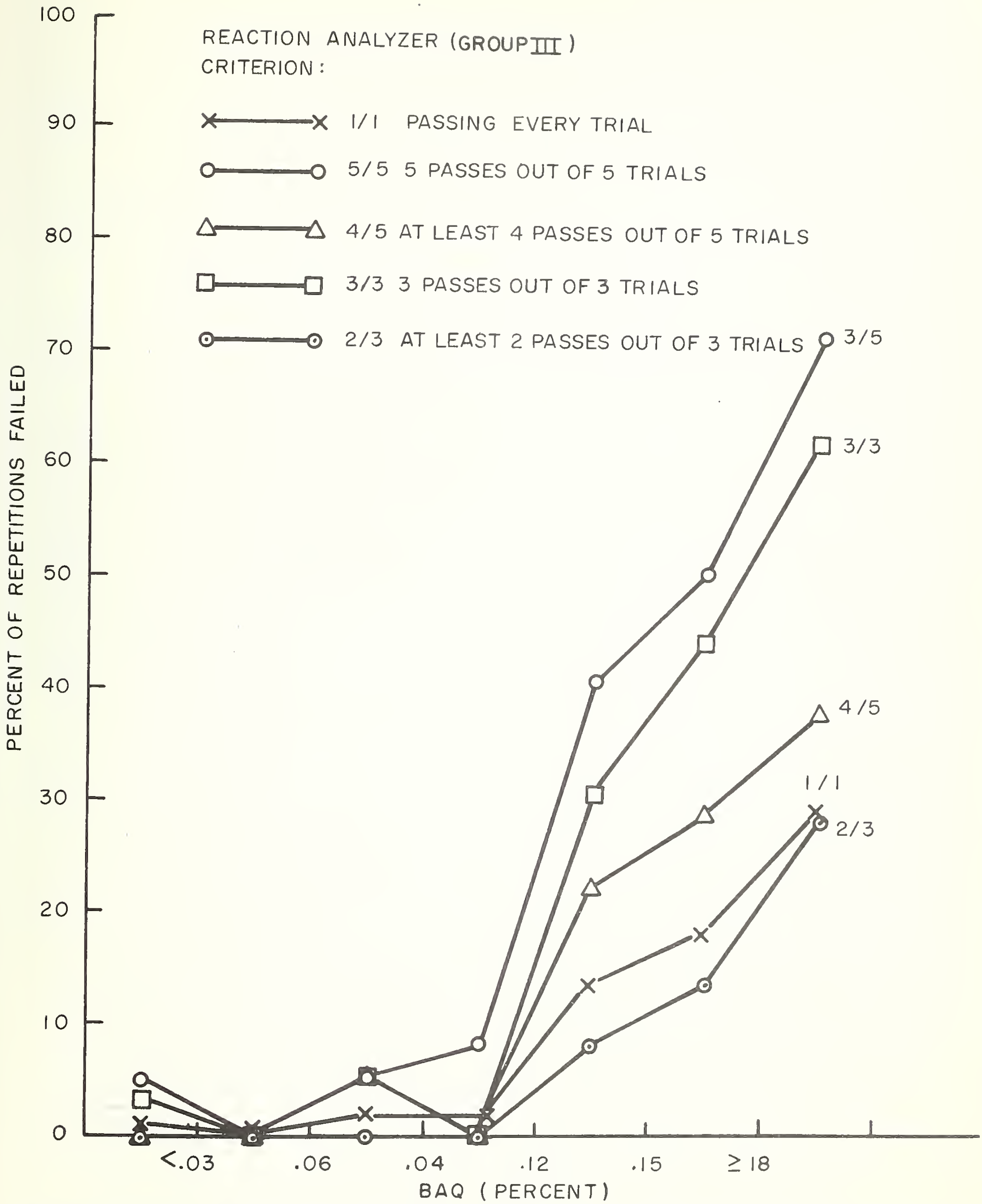

Figure A-48. Pass/Fail Performance on the Reaction Analyzer as a Function of BAQ, for Five Response Criteria

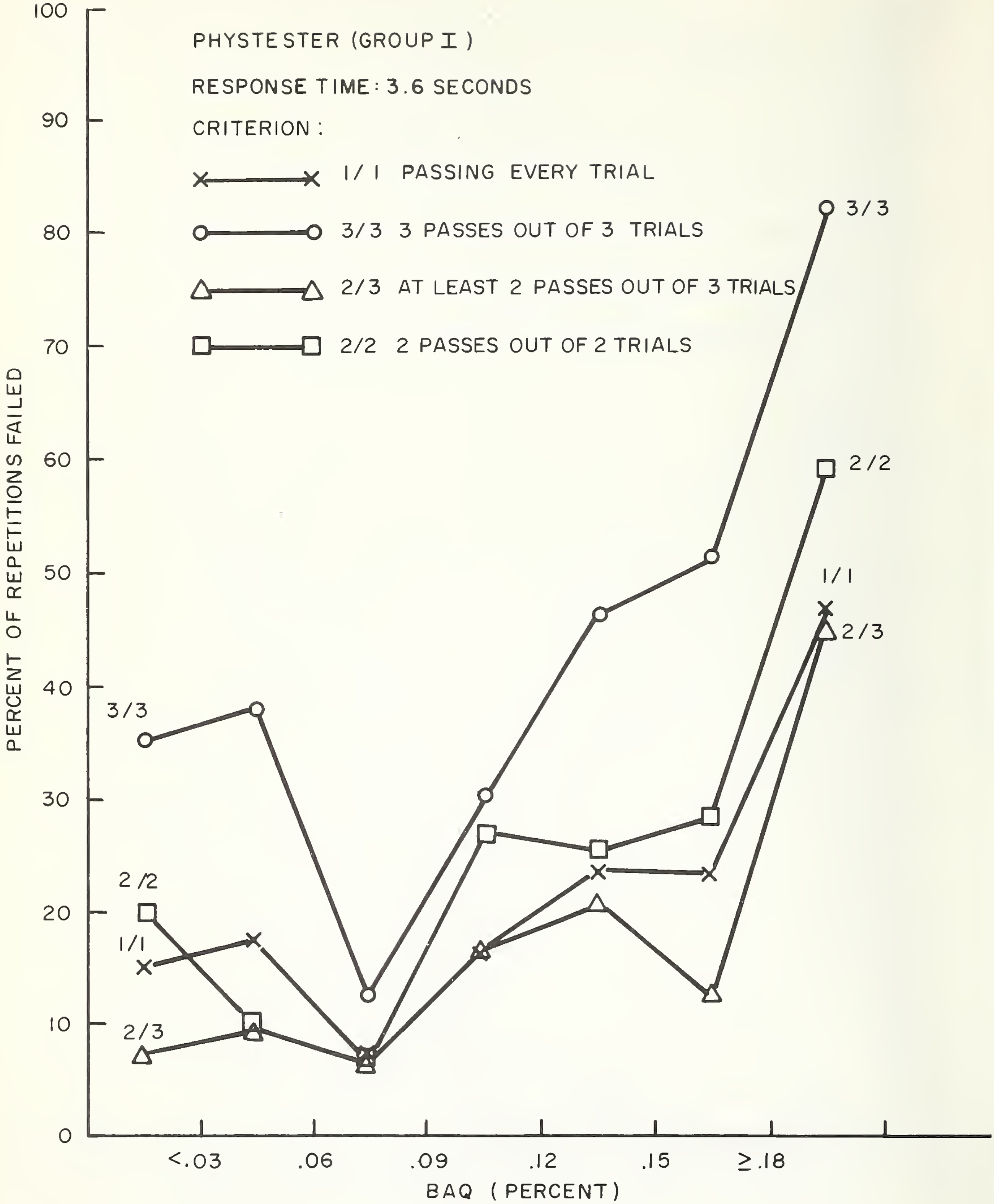

Figure A-49. Pass/Fail Performance on the Phystester as a Function of BAQ, for Four Response Criteria

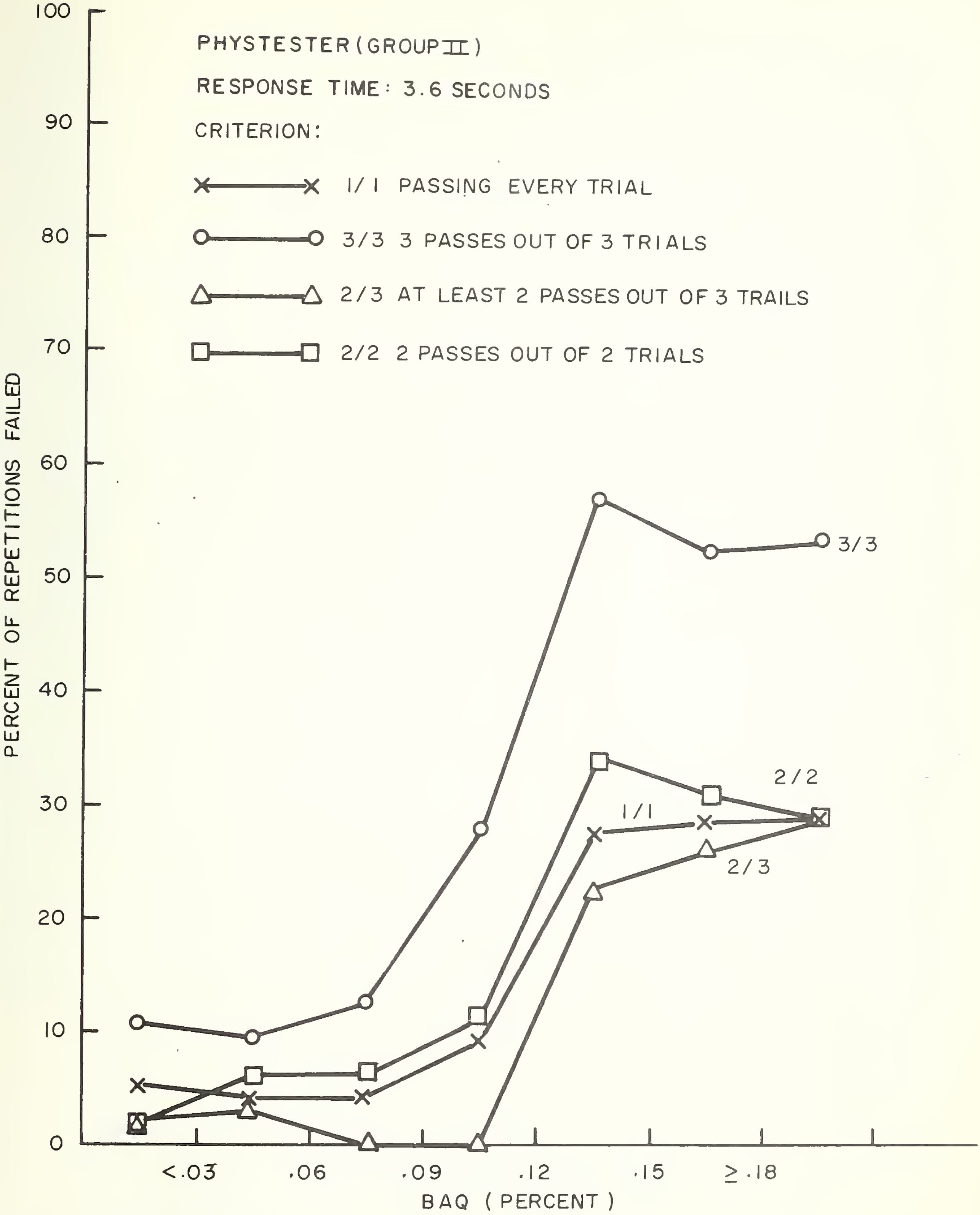

Figure A-50. Pass/Fail Performance on the Phystester as a Function of BAQ, for Four Response Criteria

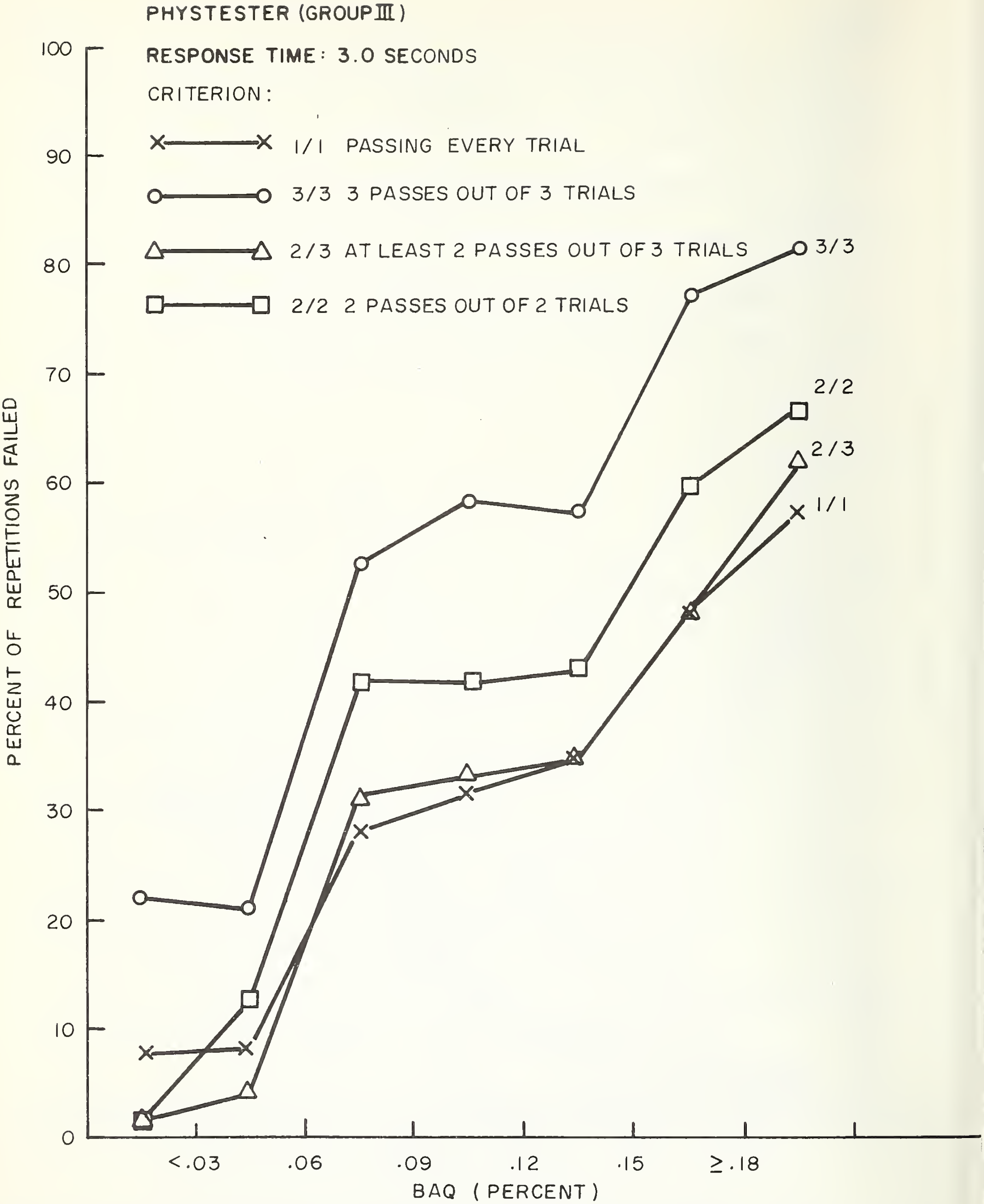

Figure A-51. Pass/Fail Performance on the Phystester as a Function of BAQ, for Four Response Criteria

Figure A-52 compares the proportions of no-starts for the High-BAQ Series subjects when drinking and when not drinking. An analysis of variance on these data (see Table A-43) indicated that both the effect of alcohol [$F(1,11)=28.02$, $p < 0.001$ and the effect of testing conditions [$F(8,88)=2.61$, $p < 0.025$] were significant. The difference due to alcohol appears for all testing conditions but 2 and 3.

It had been suggested that a person could conceivably circumvent the QuicKey by purposely reacting slowly during training, which would set the criterion window spuriously low. This problem was directly investigated during the course of these studies. Four subjects who had already been trained and tested were retrained and tested as before, but with one difference: they were to attempt to take abnormally long to react during training. This procedure raised the average allowable reaction time 38 milliseconds, from 154 to 192 milliseconds. As shown in Table A-44, this procedure was successful in circumventing the ability of the device to sense impaired performance.

In light of the following, it must be pointed out that these results merely imply an area for concern. Only four subjects participated. They had been exposed to the entire training and testing procedure before and therefore were quite familiar with the device.

b. <u>Complex-Reaction Tester</u> - Results for both BAQ Series are presented in Table A-45. A comparison of the percentages of no-starts as a function of BAQ class for both groups are essentially the same for the BAQ ranges covered ($t(6)=0.51$, $p > 0.05$).

Figure A-53 compares the proportion of no-starts for the subjects with and without alcohol. An analysis of variance on these data (Table A-46) indicated that both alcohol [$F(1,11)=15.05$, $p < .005$] and testing conditions [$F(8,88)=2.50$, $p < .025$] had significant effects. All testing conditions but the first three were significant.

Figure A-52. Comparison of the Same Subjects' Performances With and Without Alcohol on the QuicKey, using a 16th-Percentile Criterion

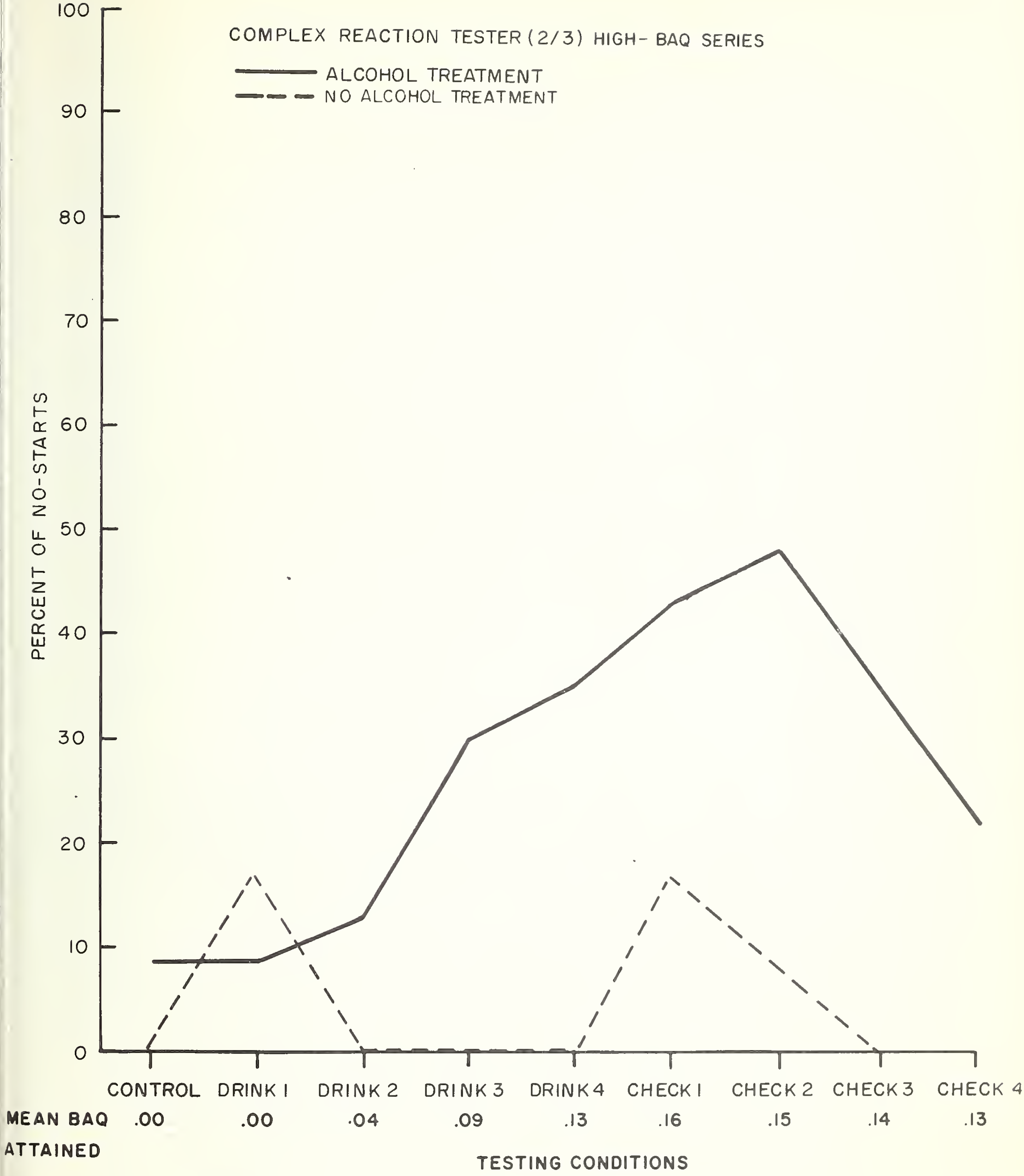

Figure A-53. Comparison of Performances of Same Subjects With and Without Alcohol the Complex-Reaction Tester, Using "At Least One Pass Out of Three Trials" Criterion

TABLE A-43. ANALYSIS-OF-VARIANCE SUMMARY

QuicKey (1 out of 1) - High-BAQ Series					
Sources of Variance	Degrees of Freedom	Sum of Squares	Mean Squares	F Ratio	Significance
Between Subjects	11	112.40	-	-	
Within Subjects	204	216.51	-	-	
Treatments	1	26.39	26.39	28.02	$p < 0.001$
Error	11	10.36	0.94	-	
Testing Condition	8	13.47	1.68	2.61	$p < 0.025$
Error	88	56.72	0.64	-	
Interaction	8	34.15	4.27	4.98	$p < 0.001$
Error	88	75.42	0.86	-	
Total	215	328.91	-	-	

Difference due to alcohol at each testing condition					
Testing Condition	df	ss	ms	F Ratio	Significance
1	1	4.73	4.73	5.44	$p < 0.025$
2	1	0.33	0.33	0.38	$p > 0.05$
3	1	0.68	0.68	0.78	$p > 0.05$
4	1	3.97	3.97	4.56	$p < 0.05$
5	1	3.70	3.70	4.25	$p < 0.05$
6	1	7.30	7.30	8.39	$p < 0.005$
7	1	15.33	15.33	17.62	$p < 0.001$
8	1	17.94	17.94	20.62	$p < 0.001$
9	1	6.57	6.57	7.55	$p < 0.01$
Error	99	85.78	0.87	-	

TABLE A-44. COMPARISON OF SUBJECTS' PERFORMANCE ON THE QUICKEY UNDER NORMAL CONDITIONS AND WHEN INSTRUCTED TO BIAS THE AVERAGE REACTION TIME

Condition	SUBJECTS' EIGHT FASTEST TIME IN MILLISECONDS	PERCENTAGE OF OBSERVED FAILURES USING 16TH PERCENTILE						
		<030%	.03-.59	.06-.089	.09-.119	.12-.149	.15-.179	≥.18%
Normal	a. 156 b. 151 c. 154 d. 153	3/16 18.8%	2/10 20.0%	2/5 40.0%	5/12 42.0%	6/13 46.2%	18/21 85.7%	8/9 88.8%
Attempting to Circumvent	a. 189 b. 195 c. 187 d. 197	0/22 0.0%	0/8 0.0%	0/6 0.0%	0/10 0.0%	0/16 0.8%	1/22 4.5%	1/12 8.3%

NOTE: All subjects were trained and tested normally and then instructed to attempt to circumvent the device by tak abnormally long to react during training, thereby setting an artificially high criterion time.

TABLE A-45. COMPARISON OF RESULTS ON THE COMPLEX-REACTION TESTER FOR BOTH BAQ SERIES EXPRESSED AS PERCENTAGE OF NO-STARTS FOR EACH BAQ, CLASS USING "AT LEAST 2 PASSES OUT OF 3 TRIALS" CRITERION

BAQ Class	High BAQ Series		Low-BAQ Series	
	%	Failure/Trials	%	Failure/Trials
<0.30%	6.8	(4/59)	8.47	(10/118)
0.300 - 0.59%	16.7	(4/24)	10.92	(13/119)
0.060 - 0.89%	10.5	(2/19)	23.00	(23/100)
0.090 - 0.119%	25.0	(9/36)	30.65	(19/62)
0.120 - 0.149%	28.6	(14/49)		
0.150 - 0.179%	44.2	(23/52)		
≥0.180%	57.1	(12/21)		

TABLE A-46. ANALYSIS-OF-VARIANCE SUMMARY

Complex Reaction Tester (2 out of 3) - High-BAQ Series					
Source of Variance	Degrees of Freedom	Sum of Squares	Mean Squares	F Ratio	Significance
Between Subjects	11	37.28	-	-	
Within Subjects	204	150.51	-	-	
Treatments	1	21.23	21.23	15.05	$p < 0.005$
Error	11	15.52	1.41	-	
Test Conditions	8	11.76	1.47	2.50	$p < 0.025$
Error	88	51.69	0.59	-	
Interaction	8	9.26	1.16	2.48	$p < 0.025$
Error	88	41.05	0.47	-	
Total	215	187.89	-	-	
Difference due to alcohol at each testing condition					
Testing Condition	df	ss	ms	F Ratio	Significance
1	1	0.41	0.41	0.72	$p > 0.05$
2	1	0.41	0.41	0.72	$p > 0.05$
3	1	0.92	0.92	1.61	$p > 0.05$
4	1	3.97	3.97	6.96	$p < 0.01$
5	1	6.22	6.22	10.91	$p < 0.005$
6	1	7.57	2.57	4.51	$p < 0.05$
7	1	7.54	7.54	13.23	$p < 0.001$
8	1	5.88	5.88	10.32	$p < 0.005$
9	1	2.57	2.57	4.51	$p < 0.05$
Error	99	56.57	0.57		

c. Reaction Analyzer - Results for the Reaction Analyzer, used in the High-BAQ Series, are presented in Table A-47. Data on the Compensatory-Tracking Device, used in the Low-BAQ Series, are presented for comparison. A comparison of the percentages of no-starts as a function of BAQ class indicates that the Reaction Analyzer performs better than the Compensatory-Tracking Tester, but that the difference is not statistically significant ($t(6)=1.41$, $p > 0.05$).

TABLE A-47. COMPARISON OF RESULTS ON THE REACTION ANALYZER, EXPRESSED AS PERCENTAGE OF NO-STARTS FOR EACH BAQ CLASS, USING "AT LEAST 3 PASSES OUT OF 3 TRIALS" CRITERION: AND ON THE COMPENSATORY-TRACKING TESTER, USING "AT LEAST 2 PASSES OUT OF 3 TRIALS" CRITERION

BAQ Class	Reaction Analyzer (High-BAQ Series)		Compensatory-Tracking Tester (Low-BAQ Series)	
	%	Failure/Trials	%	Failure/Trials
< 0.03%	3.4	(2/59)	3.39	(4/118)
0.030 - 0.059	0.0	(0/24)	3.36	(4/119)
0.060 - 0.089	5.3	(1/19)	16.00	(16/100)
0.090 - 0.119	8.3	(8/36)	25.81	(16/62)
0.120 - 0.149	30.6	(15/49		
0.150 - 0.179	44.2	(23/52)		
≥ 0.180%	61.9	(13/21)		

Figure A-54 compares the proportion of no-starts for the High-BAQ subjects on the Reaction Analyzer with and without alcohol. An analysis of variance on these data (Table A-48) indicated that alcohol had no significant effect [$F(1,11)=3.35$, $p > 0.05$], but that testing conditions were significant [$F(8,88)=2.57$, $p < .025$]. Differences between groups showed up only on testing conditions 6 and 8.

d. Phystester - Results for both BAQ series are presented in Table A-49. A comparison of the percentage of no-starts as a function of BAQ class shows that the two curves are essentially the same for the BAQ ranges concerned [$t(6)=0.53$, $p > 0.05$].

TABLE A-48. ANALYSIS-OF-VARIANCE SUMMARY

Reaction Analyzer (3 out of 3) - High-BAQ Series

Source of Variance	Degrees of Freedom	Sum of Squares	Mean Squares	F-Ratio	Significance
Between Subjects	11	40.17	-	-	
Within Subjects	204	188.48	-	-	
Treatments	1	7.34	7.34	3.35	$p > 0.05$
Error	11	24.12	2.19	-	
Testing Condition	8	11.64	1.46	2.57	$p < 0.025$
Error	88	49.87	0.57	-	
Interaction	8	27.49	3.44	4.45	$p < 0.001$
Error	88	68.02	0.77	-	
Total	215	228.65	-	-	

Differences due to alcohol at each testing condition

Testing Condition	df	ss	ms	F Ratio	Significance
1	1	0.10	0.10	0.11	$p > 0.05$
2	1	2.57	2.57	2.76	$p > 0.05$
3	1	0.92	0.92	0.99	$p > 0.05$
4	1	0.92	0.92	0.99	$p > 0.05$
5	1	3.18	3.18	3.42	$p > 0.05$
6	1	9.14	9.14	9.83	$p < 0.005$
7	1	9.83	9.83	10.57	$p < 0.005$
8	1	4.73	4.73	5.09	$p < 0.05$
9	1	3.44	3.44	3.70	$p > 0.05$
Error	99	92.14	0.93	-	

TABLE A-49. COMPARISON OF RESULTS ON THE PHYSTESTER FOR BOTH BAQ SERIES EXPRESSED AS A PERCENTAGE OF NO-STARTS FOR EACH BAQ CLASS, USING "AT LEAST 2 PASSES OUT OF 3 TRIALS" CRITERION

BAQ Class	High-BAQ Series		Low-BAQ Series	
	%	Failures/Trials	%	Failures/Trials
< 0.03%	1.7	(1/59)	1.69	(2/118)
0.030 - 0.059 %	4.2	(1/24)	5.88	(7/119)
0.060 - 0.089 %	31.6	(6/19)	11.00	(11/100)
0.090 - 0.119 %	33.3	(12/36)	24.19	(15/62)
0.120 - 0.149 %	34.7	(17/49)		
0.150 - 0.179 %	48.1	(25/52)		
≥ 0.180 %	61.9	(13/21)		

The graph in Figure A-55 compares the proportion of no-starts for the High-BAQ Subjects with and without alcohol. An analysis of variance of the data (Table A-50) indicated that both alcohol [$F(1,11)=17.92$, $p < .005$] and testing conditions [$F(8,88)=5.80$, $p < .001$] were significant effects. The difference between treatments appeared after the fourth testing condition.

A-3.2.2.1 Comparison of Performances

Finally, a comparison of the percentage of no-start performance on the four devices tested in the High-BAQ series are presented as a function of BAQ class intervals in Table A-51 below.

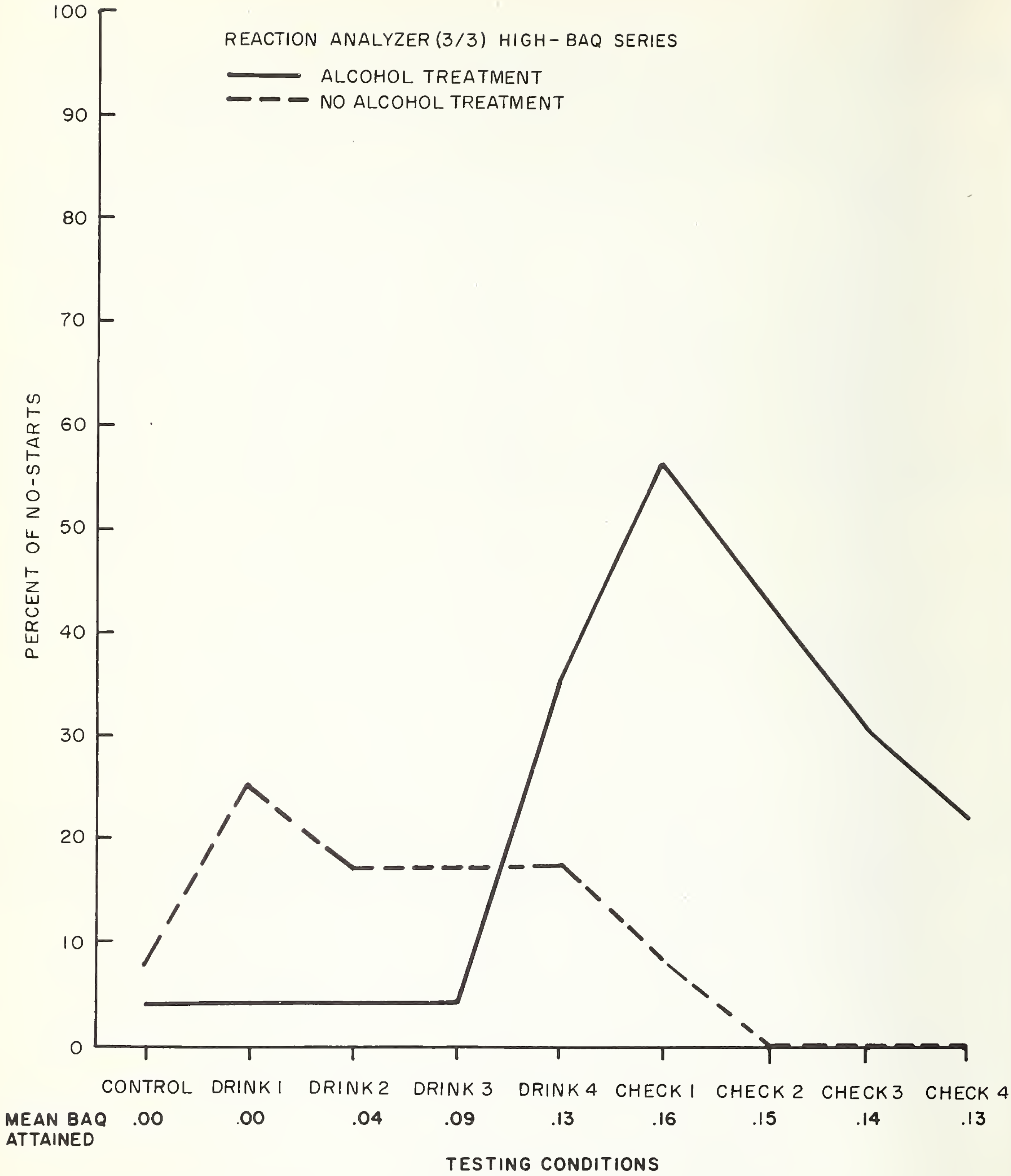

Figure A-54. Comparison of Performances of Same Subjects With and Without Alcohol Reaction Analyzer, Using "At Least Three Passes Out of Three Trials" Criterion

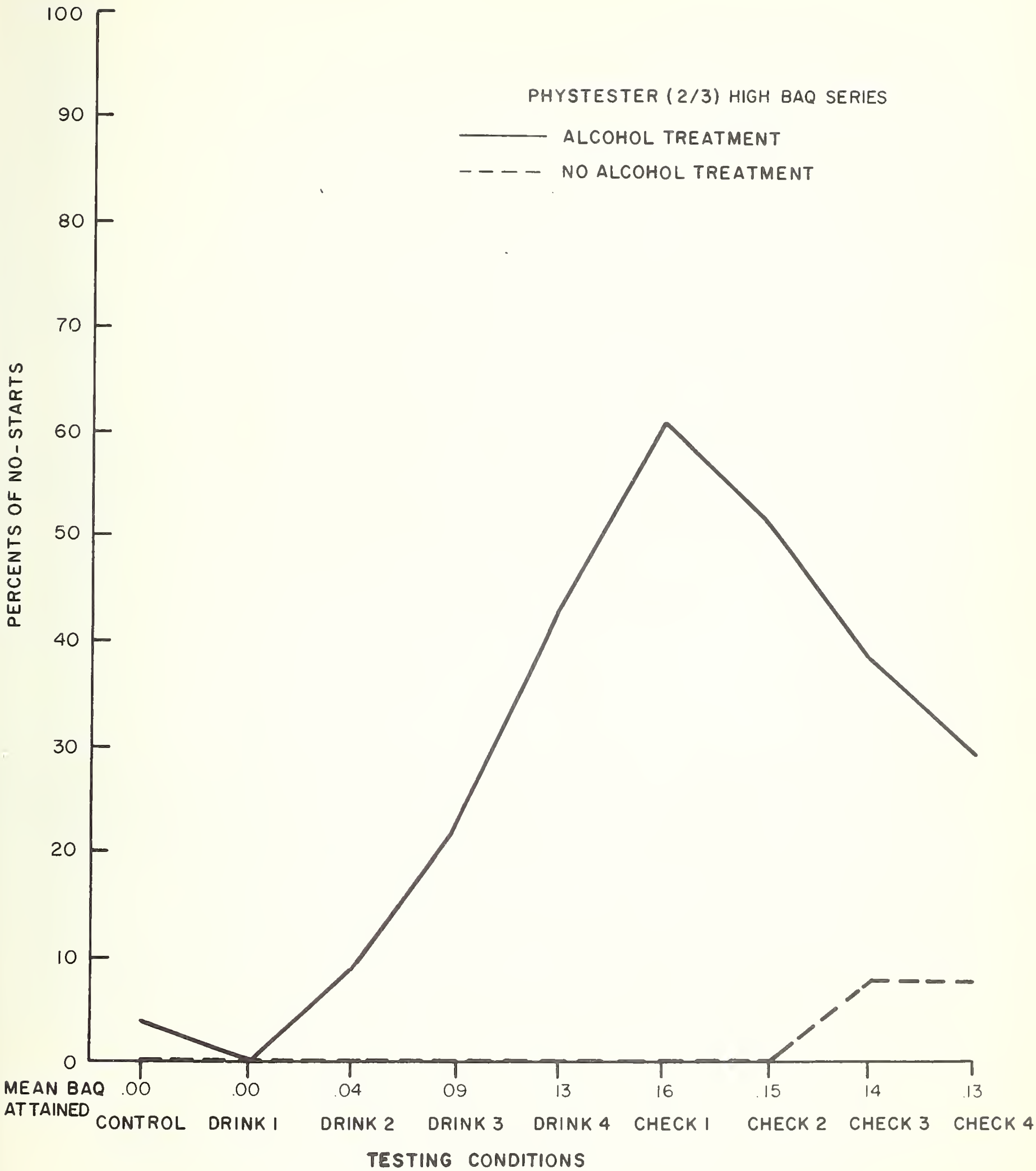

Figure A-55. Comparison Performance of Same Subjects With and Without Alcohol on the Phystester, Using "At Least Two Passes out of Three Trials" Criterion

TABLE A-50. ANALYSIS-OF-VARIANCE SUMMARY

Phystestor (2 out of 3) - High-BAQ Series					
Source of Variance	Degrees of Freedom	Sum of Squares	Mean Squares	F Ratio	Significance
Between Subjects	11	26.85	-	-	
Within Subjects	204	182.21	-	-	
Treatments Error	1 11	34.52 21.19	34.52 1.93	17.92 -	P<0.005
Test Condition Error	8 88	20.69 39.27	2.54 0.45	5.80 -	p<0.001
Interaction Error	8 88	18.49 48.05	2.31 0.55	4.23 -	p<0.001
Total	215	209.06	-	-	

Difference due to alcohol at each testing condition					
Testing Condition	df	ss	ms	F Ratio	Significance
1	1	0.10	0.10	0.14	p>0.05
2	1	0.00	0.00	0.00	p>0.05
3	1	0.41	0.41	0.59	p>0.05
4	1	2.57	2.54	3.67	p>0.05
5	1	12.43	12.43	17.76	p<0.001
6	1	17.36	17.36	24.80	p<0.001
7	1	12.92	12.92	18.46	p<0.001
8	1	4.43	4.43	6.33	p<0.025
9	1	2.79	2.79	3.99	p<0.05
Error	99	69.24	0.70	-	

A start/no-start discriminant score for each device is presented in the final row. The same data are presented graphically in Figure A-56.

TABLE A-51. PERCENTAGE OF NO-STARTS AS A FUNCTION OF BAQ CLASS FOR THE HIGH BAQ SERIES

BAQ Class	No. of Data Points	Complex-Reaction Tester	QuicKey	Reaction Analyzer	Phystester
<.03%	59	6.8%	8.5%	3.4%	1.7%
.030-.059	24	16.7	16.7	0.0	4.2
.060-.089	19	10.5	21.1	5.3	31.6
.090-.119	36	25.0	41.0	8.3	33.3
.120-.149	49	28.6	38.8	30.6	34.7
.150-.179	52	44.2	59.6	44.2	48.1
≤.180	21	57.1	61.9	61.9	61.9
Difference between lowest and highest BAQ class score		50.3	53.4	58.5	60.2

A-3.3 EFFECTS OF VARIOUS FACTORS

During the course of the studies reported in both Volumes II and III, the roles of certain factors were observed. In Volume II, factors such as the past history of subjects, and their age, gender and IQ are treated. The work reported in Volume III involved explorations of specific problems which might become important in implementing an operational ASIS program. The effect of extremely high motivation levels was also studied, since a driver's motivation to start his car is sometimes very high. Certain aspects of training and the effects of overtraining were also explored.

A-3.3.1 <u>Subject Factors</u>

A-3.3.1.1 <u>Drinking History</u> - <u>Registry Versus Social</u> - During a portion of the study, as reported in Volume II, two types of subjects were tested: social and registry. Social subjects included those who had no history of alcohol-related driving offenses resulting in arrest. They were light-to-moderate

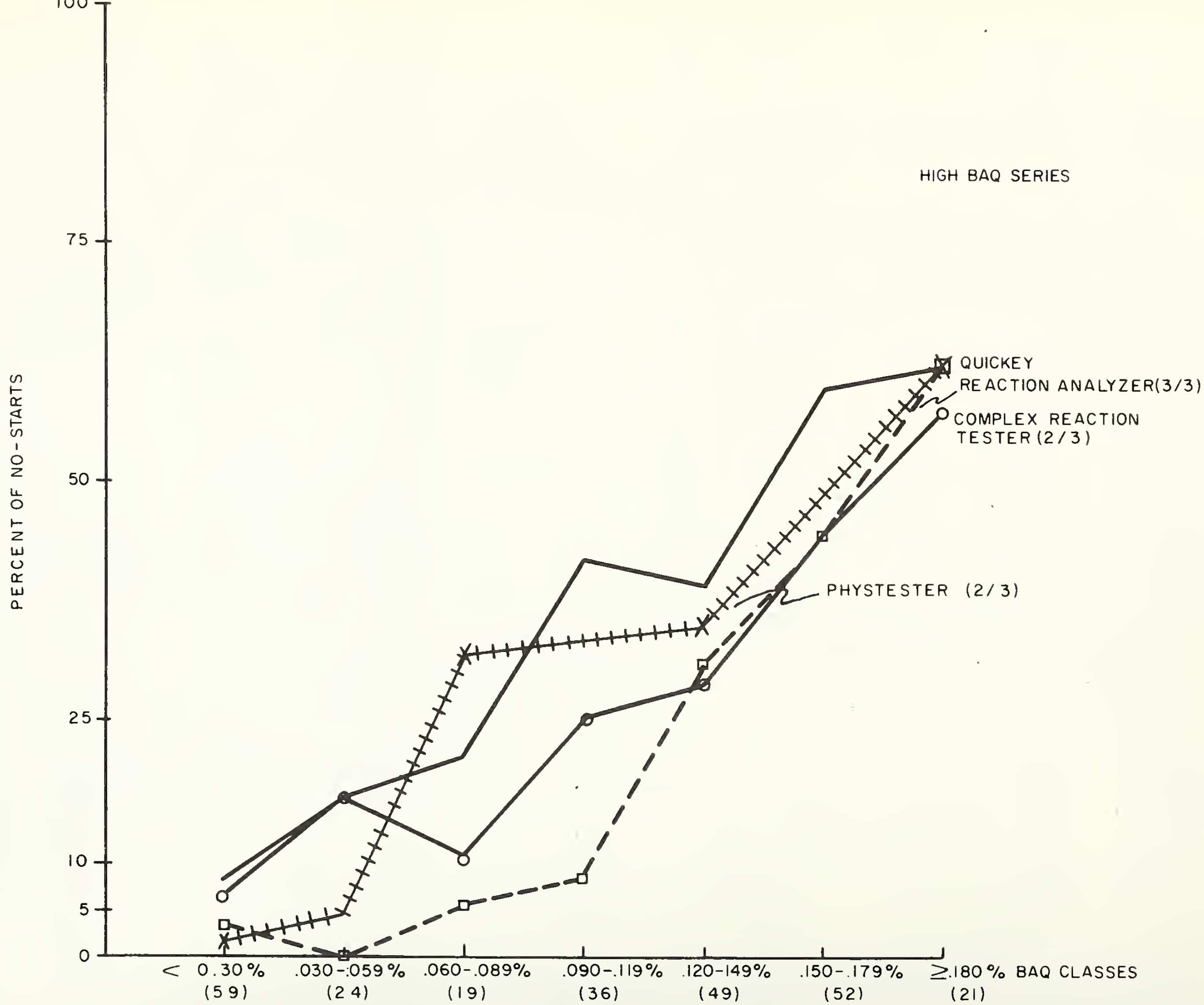

Figure A-56. Relation Between BAQ and Percentage of No-Starts on Each Device, Using "At Least Two Correct Responses"* as the Criterion for Starting

*Since the QuicKey was scored on the basis of a single response, this criterion does not apply.

users of alcohol, ranging in age from 21 to 70 with a mean of 29 years. Registry subjects included those who did have a history of at least one arrest for driving while intoxicated. They were generally heavy alcohol users, and ranged from age 21 to 62 with a mean of 35 years. The performances of these two groups were compared to determine whether there are any differences between them which might be important to an actual ASIS program, especially since registry drivers might be the first targets of such a program. Results will be discussed individually for each device.

a. Pilot Studies -

QuicKey and Complex-Reaction Testers - Only two registry subjects were tested on the QuicKey device and only one on the Complex-Reaction Tester, as compared to 10 and 17 social subjects, respectively. In neither case were there enough registry subjects for a meaningful comparison.

Compensatory-Tracking Tester - Figure A-57 shows the mean integrated-absolute-position error (in volt-seconds) for 20 social and 12 registry subjects as a function of testing condition. The registry subjects performed consistently worse than the social subjects, and this difference was significant [$t(1.18)=5.51$, $p < .001$].

Phystester - Figure A-58 compares the performance on the Phystester of 12 registry and 20 social subjects. Median number of passes is plotted as a function of testing condition. A t-test showed the mean performance of the 20 social subjects to be significantly better than that of the 12 registry subjects [$p < 0.025$].

b. Low-BAQ Series - Comparison of the pass/fail performance scores of registry and social subjects are presented in Figures A-59 through A-62. The data include the scores of only two registry subjects, as compared to 17 social-drinking subjects; however, such a comparison can be useful with pass/fail criterion.

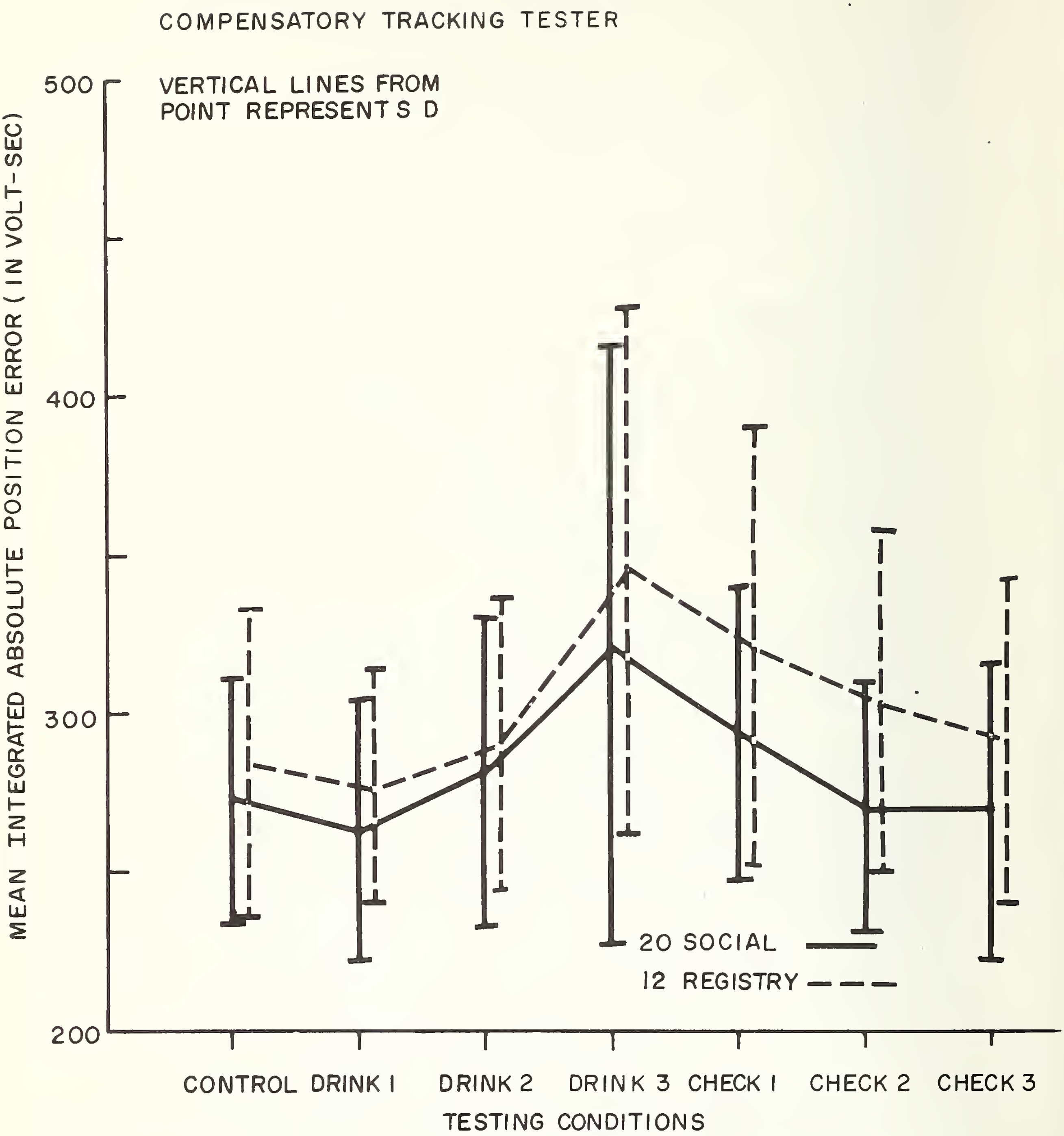

Figure A-57. Performance on the Compensatory-Tracking Tester as a Function of Testing Condition for 20 Social and 12 Registry Subjects

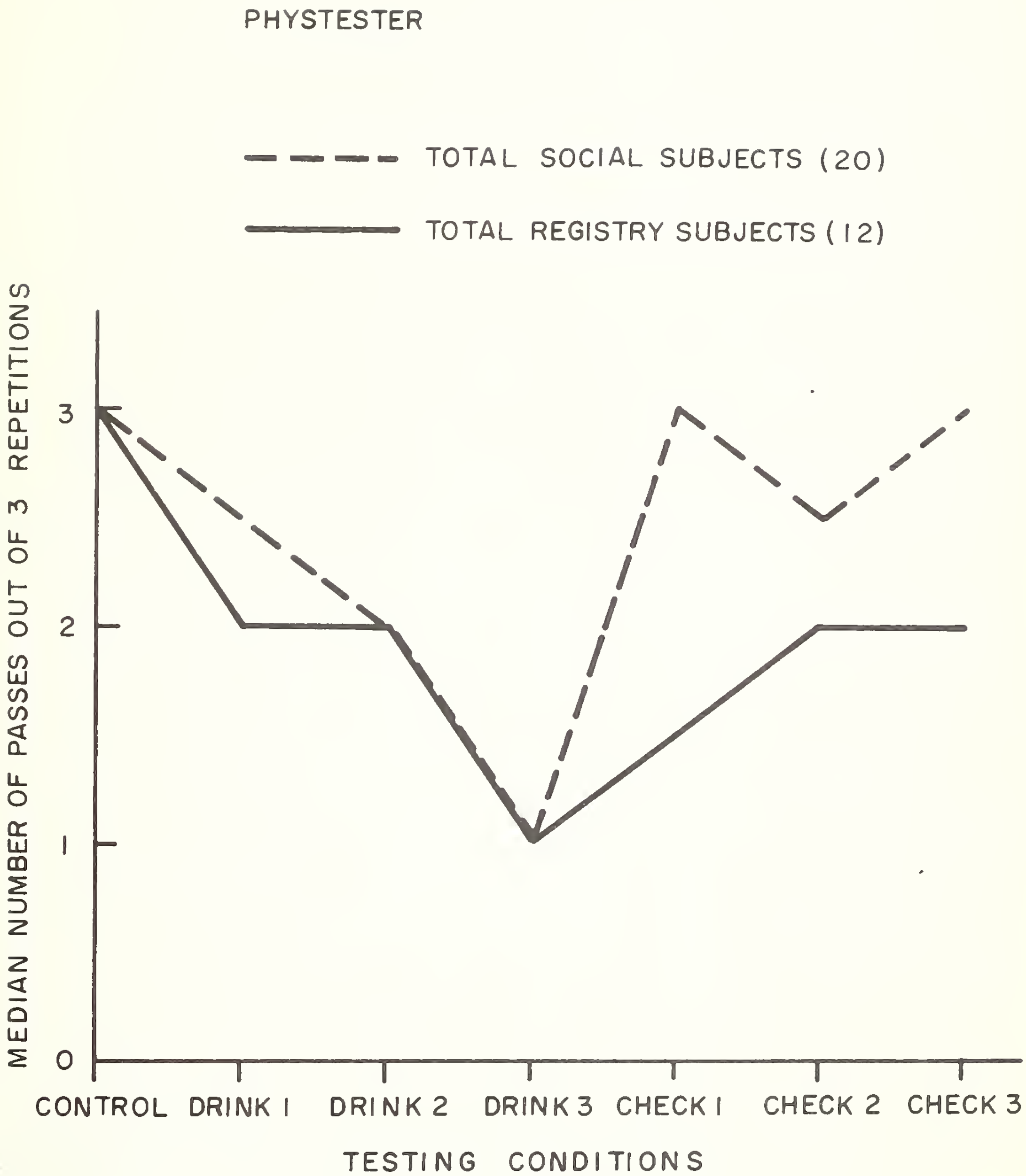

Figure A-58. Performance on the Phystester as a Function of Testing Condition for 20 Social and 12 Registry Subjects

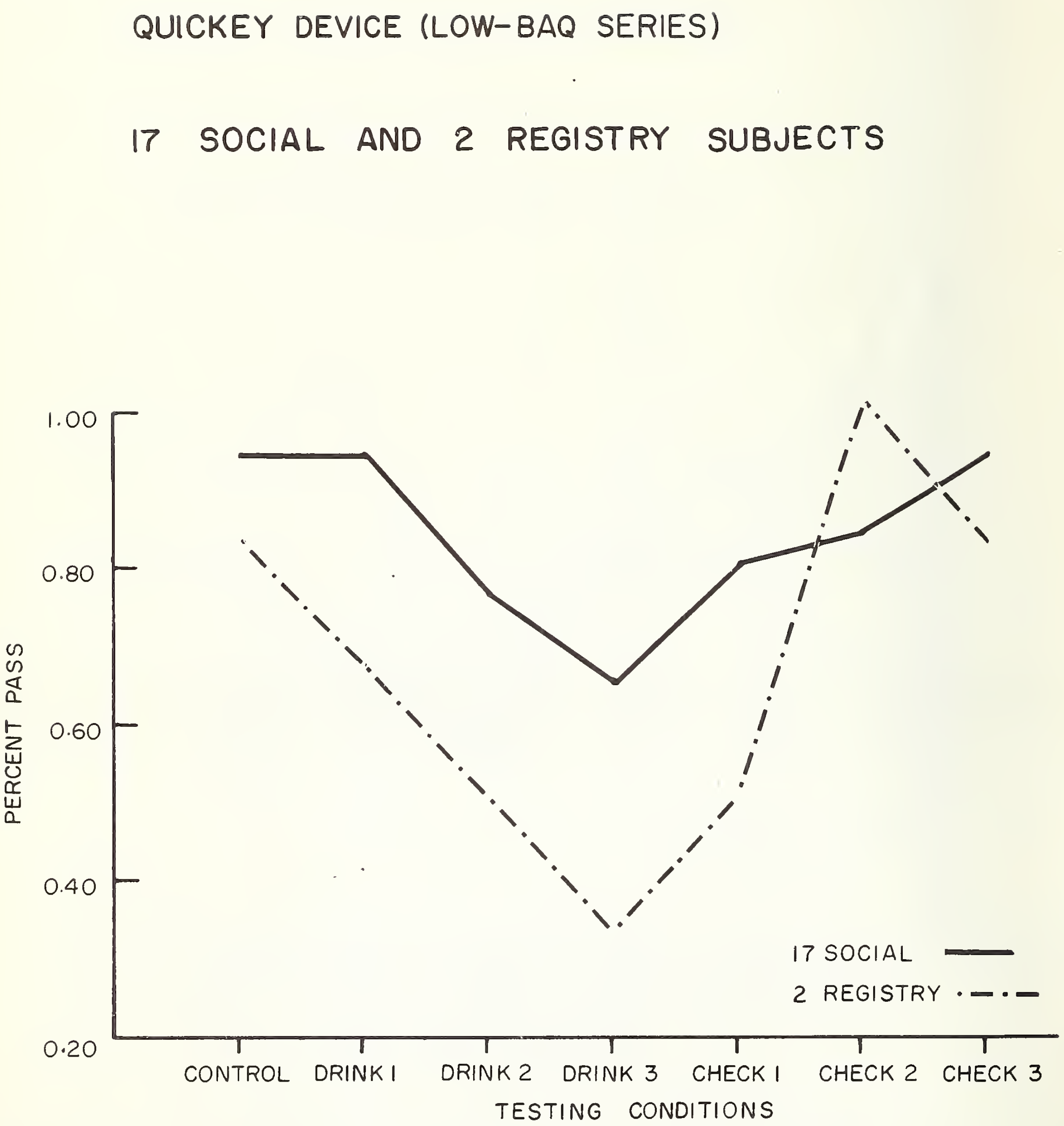

Figure A-59. Pass/Fail Performance on the QuicKey Device as a Function of Testing Condition for Two Registry and 17 Social Subjects

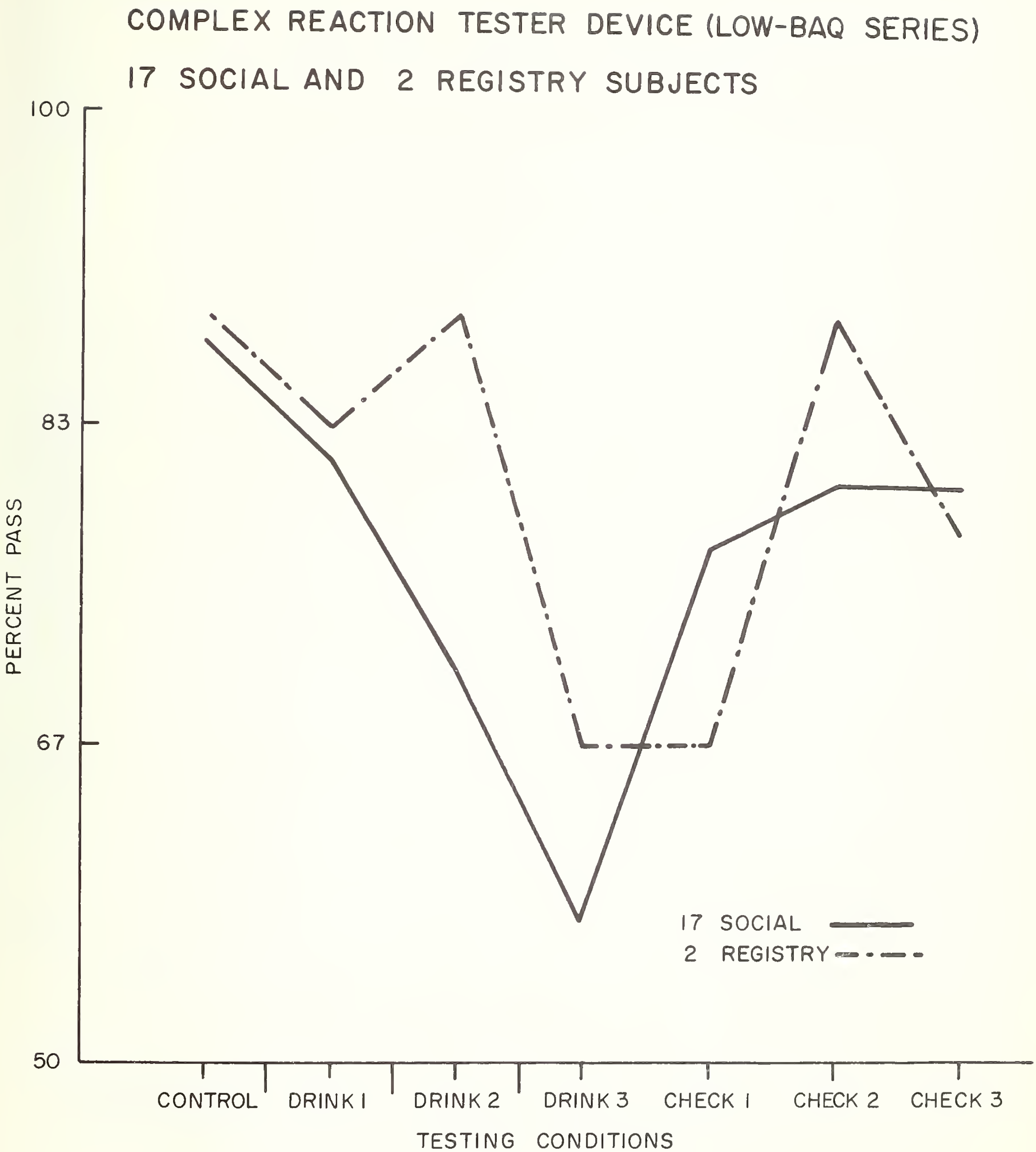

Figure A-60. Pass/Fail Performance on the Complex-Reaction Tester as a Function of Testing Condition for Two Registry and 17 Social Subjects

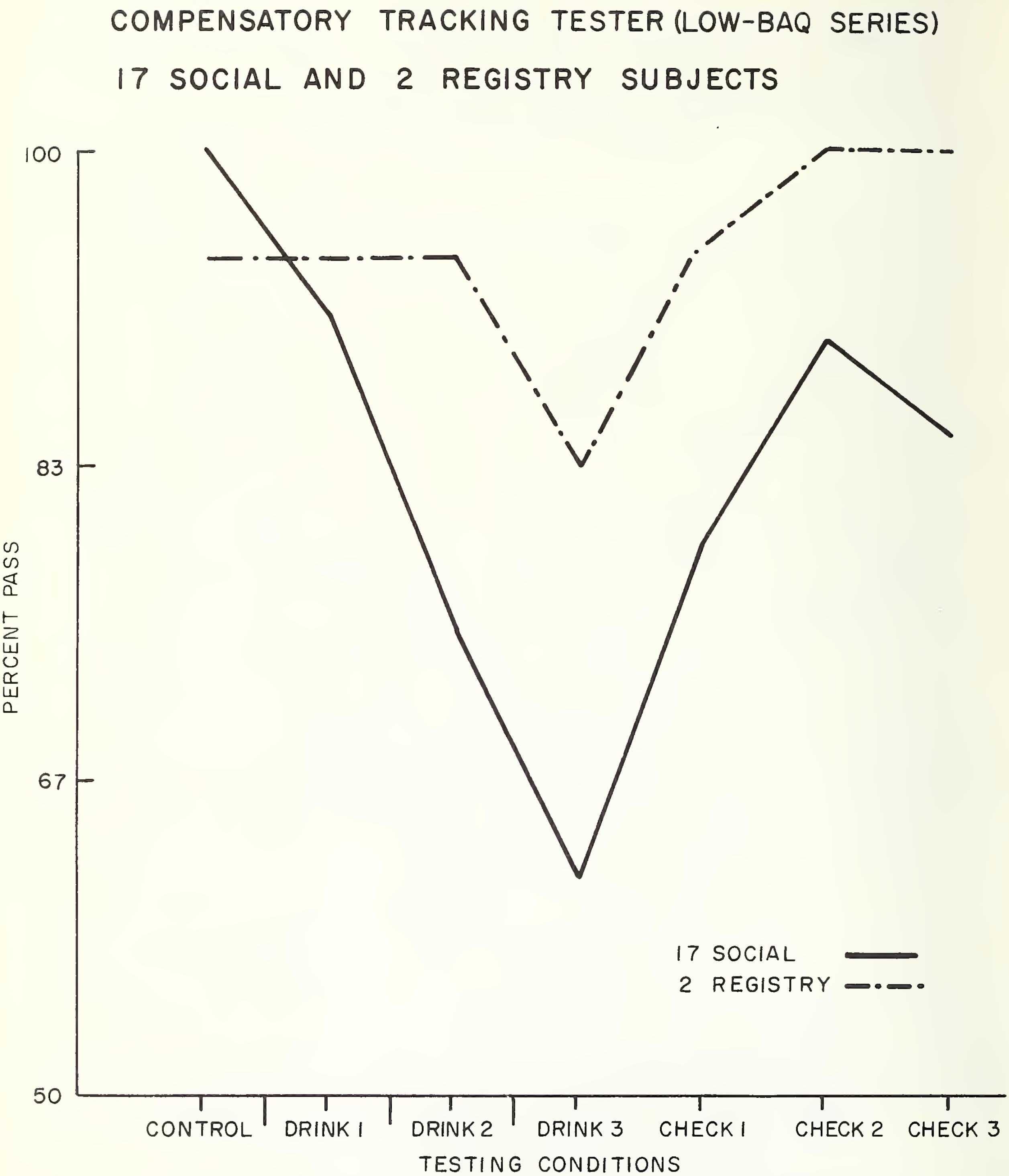

Figure A-61. Pass/Fail Performance on the Compensatory-Tracking Tester as a Function of Testing Condition for Two Registry and 17 Social Subjects

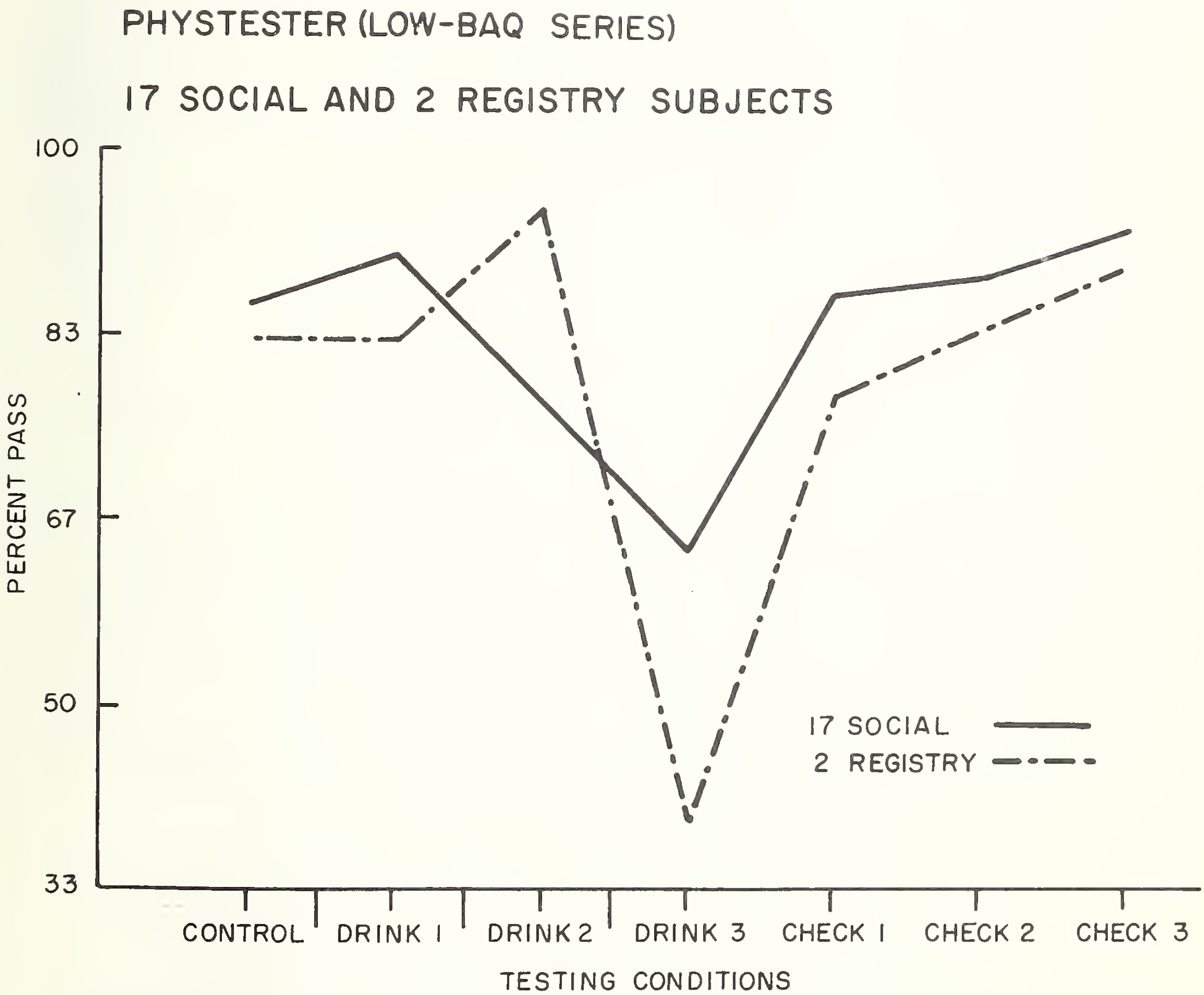

Figure A-62. Pass/Fail Performance on the Phystester as a Function of Testing Condition for Two Registry and 17 Social Subjects

There appear to be no consistent differences in the performance of the two subject groups, as can be seen from the graphs. Note that the registry subjects tended to perform better on the Complex-Reaction and the Compensatory-Tracking testers. However, they performed worse on the QuicKey device, and about as well as the social subjects on the Phystester. Thus, it appears at present that differences are specific to the devices employed.

A-3.3.1.2 Age - The age of the 37 subjects whose performance is reported in Volume III averaged 33.2 years and ranged from 21 to 63 years. As shown in Table A-52, age effects did appear for certain devices, specifically the QuicKey and the Reaction Analyzer. The QuicKey is a reaction-time task, and reaction time is known to vary with age. The Reaction Analyzer is a tracking device which was introduced in the middle of testing. During the first session with the Reaction Analyzer, differences as a function of age were discovered. However, these differences were eliminated in the succeeding session by providing extended training for the older subjects. It is presumed that proper training will eliminate this age effect on the QuicKey as well.

A-3.3.1.3 Gender - A comparison of performance by gender is reported in Volume II for the QuicKey device; a t-test showed no overall statistical difference in performance between the six male and five female social subjects. For the Complex-Reaction Tester, a t-test showed that the 12 male social drinking subjects made significantly more errors that the five female social drinking subjects.

Thirty-seven subjects, 20 males and 17 females, were tested in three groups in the work reported in Volume II. Each group was tested on all devices and an analysis of variance performed on the results. Table A-53 presents F scores comparing the performance of the males and females on each device. Gender had no significant effects upon performance on any of the devices tested.

TABLE A-52. F SCORES COMPARING THE PERFORMANCE OF SUBJECTS OLDER AND YOUNGER THAN 30, WITH LEVELS OF SIGNIFICANCE

Device	Group I	Group II	Group III
QuicKey (1 pass within 2 minutes for 16th % window)	16.47 $p < 0.01$	34.72 $p < 0.01$	0.14* $p > 0.05$
Complex Reaction Tester (3 passes out of 3 trials)	4.25 $p > 0.05$	3.79 $p > 0.05$	0.33 $p > 0.05$
Reaction Analyzer (at least 4 passes out of 5 trials)	——	11.25** $p < 0.05$	0.02 $p > 0.05$
Phystester (at least 2 passes out of 3 trials)	.013 $p > 0.05$	2.75 $p > 0.05$	1.33 $p > 0.05$

*No subjects older than 39 years.

**Probably due to inadequate training of older subjects.

TABLE A-53. F SCORES COMPARING THE PERFORMANCE OF MALES AND FEMALES (NON-SIGNIFICANT)

Device	Group I	Group II	Group III
QuicKey (1 pass within 2 minutes for 16th % possible window)	1.88 N. S.	3.30 N. S.	0.07 N. S.
Complex Reaction Tester (3 passes out of 3 trials)	0.64 N. S.	2.31 N. S.	5.15 N. S.
Reaction Analyzer (at least 4 passes out of 5 trials)	-- --	1.60 N. S.	0.47 N. S.
Phystester (at least 2 passes out of 3 trials)	0.003 N. S.	0.15 N. S.	3.58 N. S.

A-3.3.1.4 I.Q. - Table A-54 reviews the correlation between total I.Q. score and performance on the four devices for the testing reported in Volume II. The only significant correlation observed was for the social subjects on the Complex-Reaction Tester. However, the correlation is small and is probably an artifact.

A-3.3.2 Different Motivation Levels - The motivation scheme (bonus moneys) used in the training and testing reported in Volume III are described in Table A-55.

Figure A-63 shows that for the QuicKey device (16th-percentile criterion) Group III (no bonus) performed best, especially at low BAQ's. Perhaps the high pay-offs of Groups I and II led to over-arousal of these subjects. For the Complex-Reaction Tester (2/3 criterion), Figure A-64 shows that Group III had a higher failure rate at BAQ levels above .03 than Group I. It may be hypothesized that this observed difference was due to the fact that Group III received immediate feedback when they failed, whereas Group I found out only at the end of a block of trials whether or how often they had failed.

Figure A-65 shows that the performance on the Reaction Analyzer (4/5 criterion) of Group II subjects was poorer than that of Group III subjects at low BAQ levels. However, note the performance of those subjects less than 30 years old: age apparently affects performance on this device, a factor which was overcome in Group III by better training.

Figure A-66 compares the effect of different motivation levels for the Phystester. The only real effect was found in Group III, where the permissible duration of the task was shortened from 3.6 to 3.0 seconds.

Generally, those motivation levels which could be considered high appear to raise the frequency of no-starts at low BAQ levels. This effect may be a source of difficulty for those anxious to start their cars.

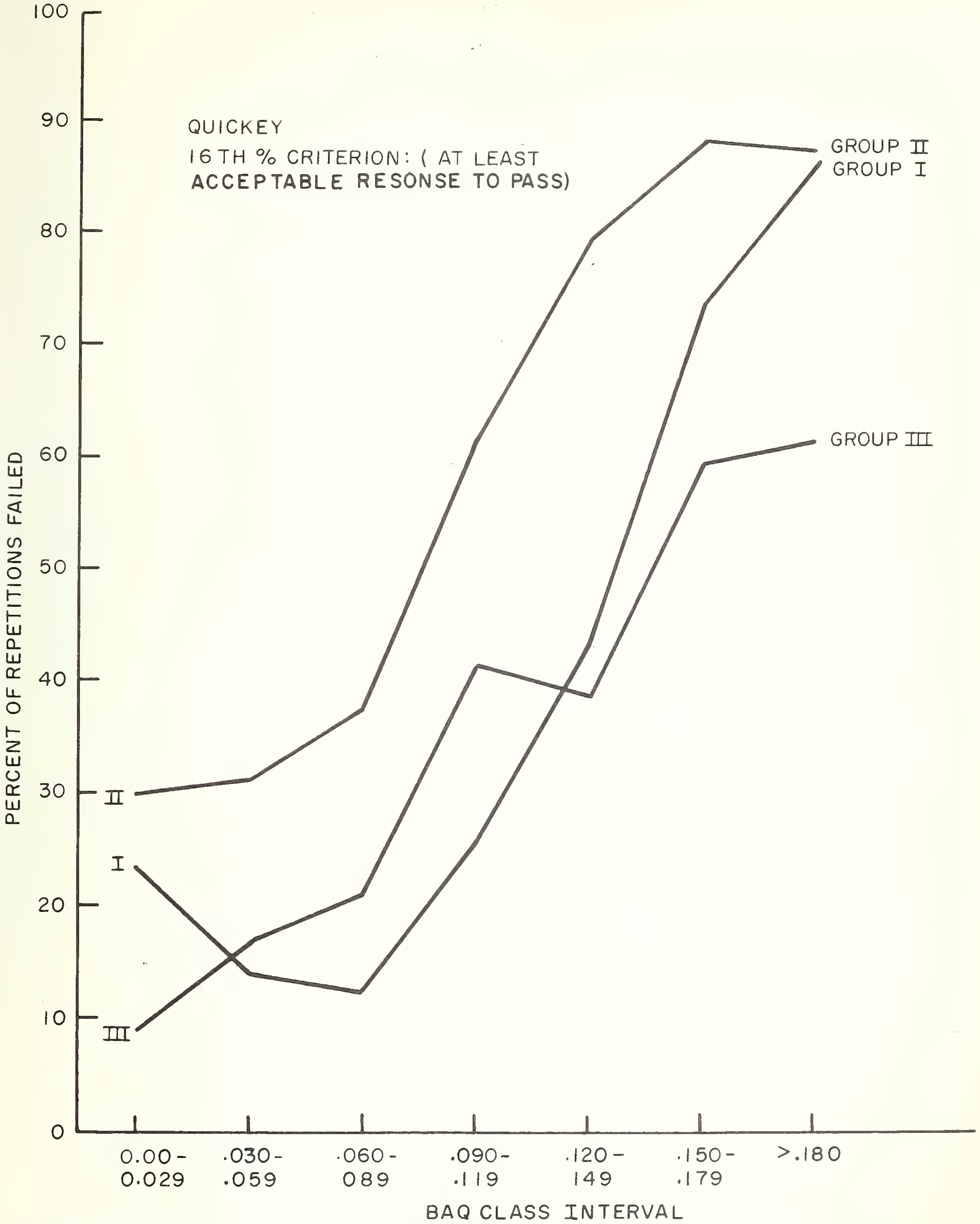

Figure A-63. Pass/Fail Performance on the QuicKey for Three Motivation Levels as a Function of BAQ (16th-Percentile Criterion)

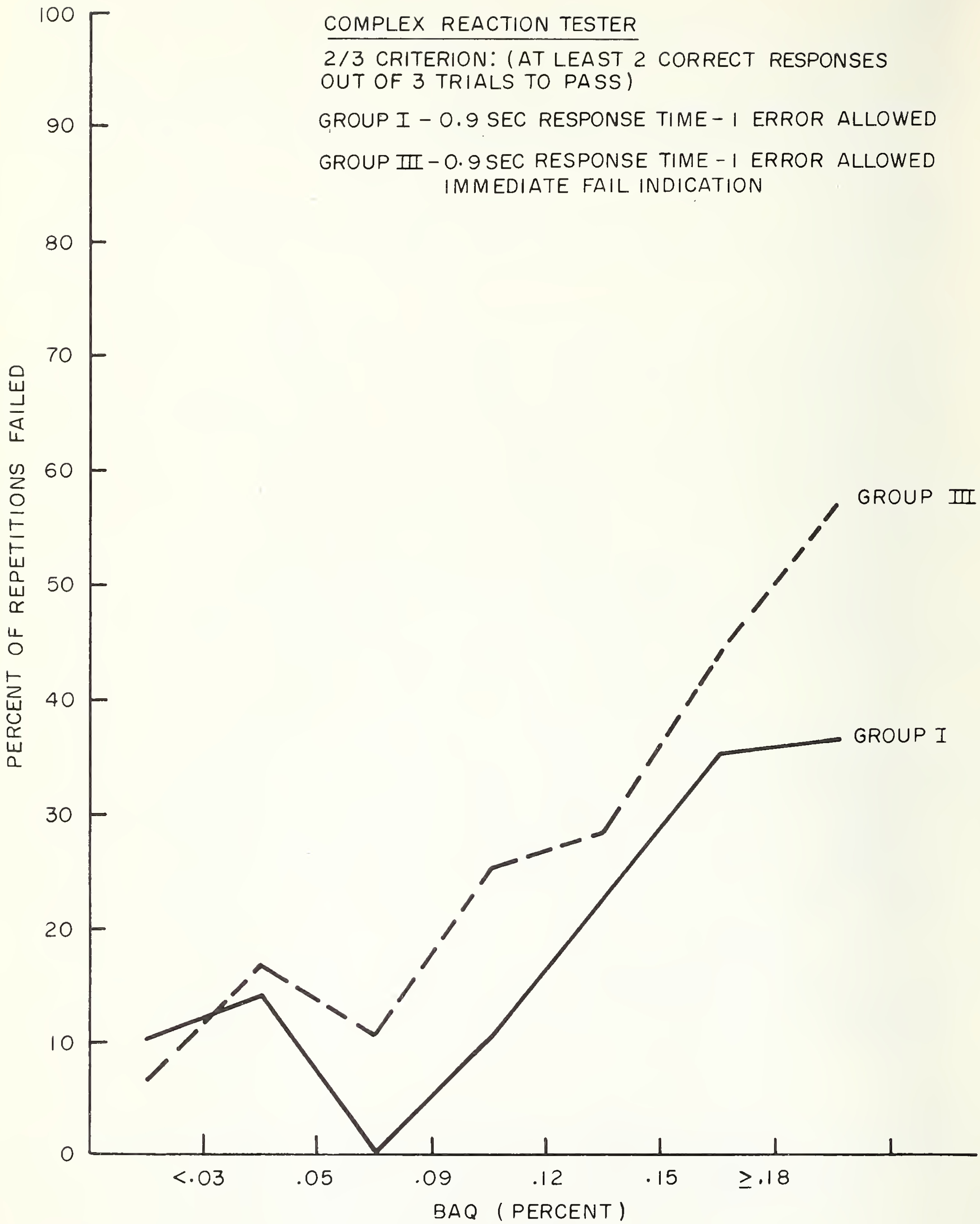

Figure A-64. Pass/Fail Performance on the Complex-Reaction Tester as a Function of BAQ for Two Motivation Levels

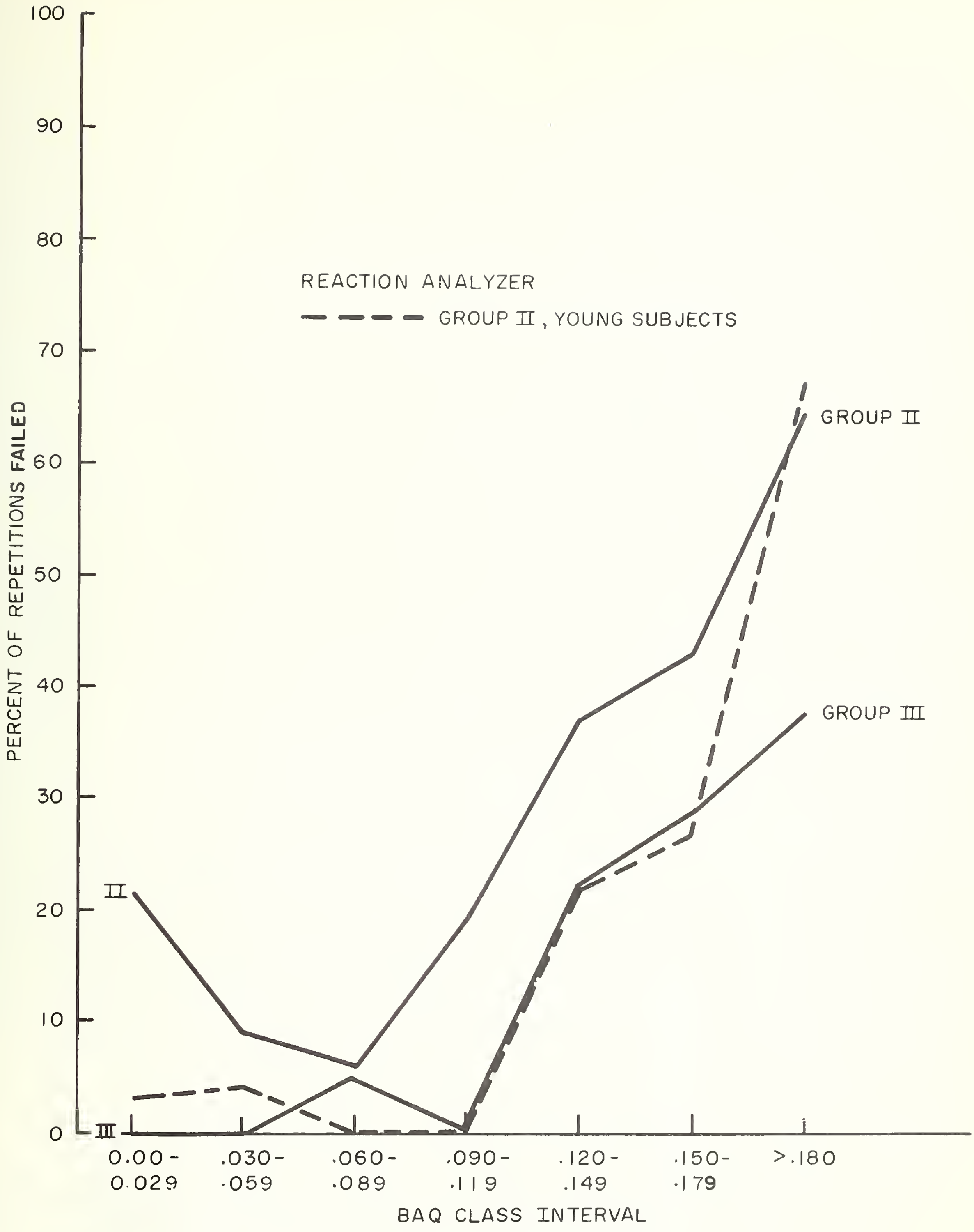

Figure A-65. Pass/Fail Performance on the Reaction Analyzer as a Function of BAQ for Two Motivation Levels

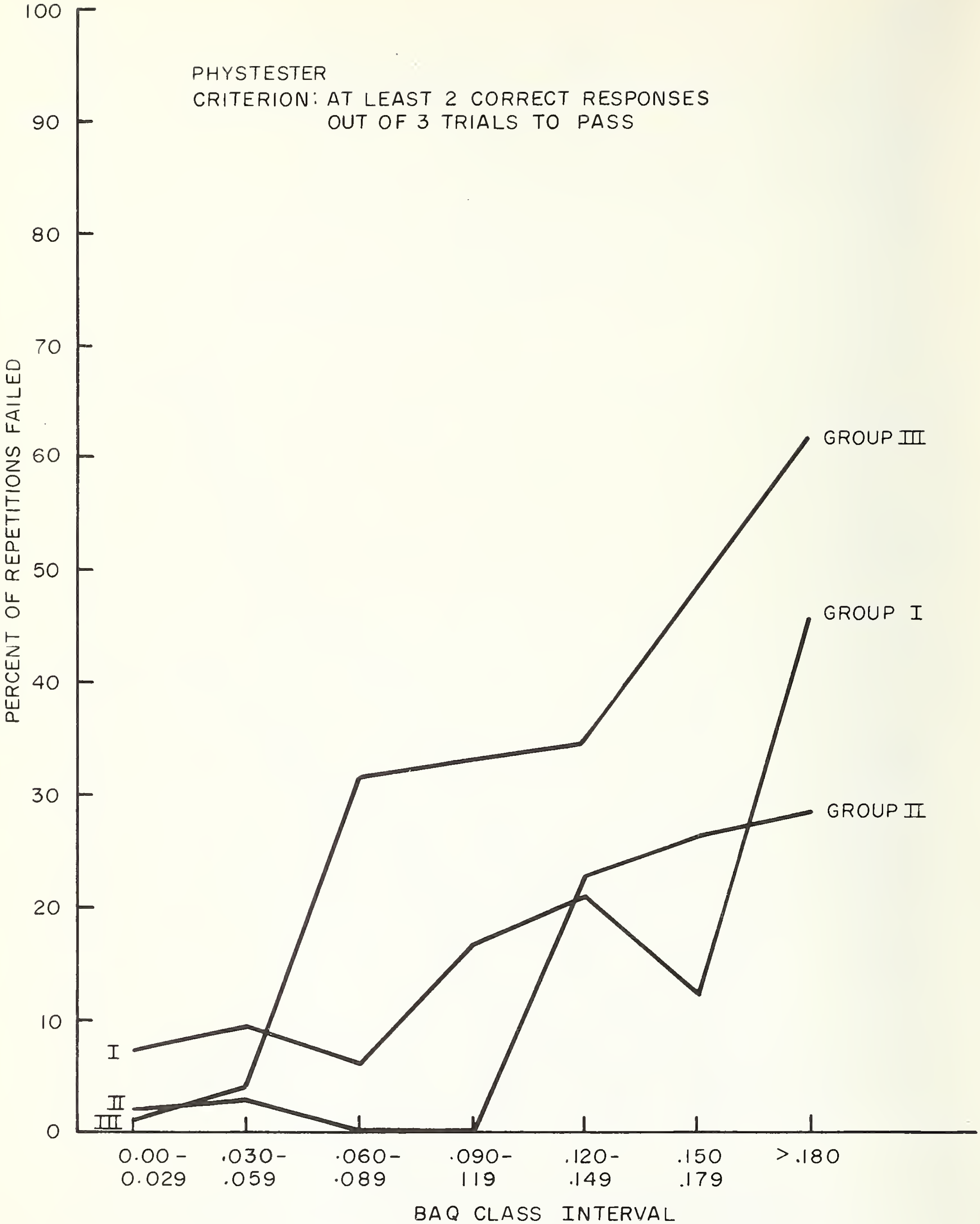

Figure A-66. Pass/Fail Performance on the Phystester as a Function of BAQ for Three Motivation Levels

TABLE A-54. CORRELATION BETWEEN IQ AND PERFORMANCE ON EACH DEVICE

Type and No. of Subjects	Verbal Percentile Score	Numerical Percentile Score	Total Mean I.Q.	QuicKey	Complex Reaction Tester	Compensatory-Tracking Tester (No. of Errors)	Phystester
Social (48)	63.88	52.69	57.02	-0.13 $p > 0.05$	-0.53 $p < 0.01$	-0.11 $p > 0.05$	0.32 $p > 0.05$
Registry (13)	73.00	57.46	--*	--		-0.24 $p > 0.05$	0.19 $p > 0.05$
Control (6)	70.00	53.33	64.83	--	0.50 $p > 0.05$	-0.39 $p > 0.05$	--
Pass/Fail Subjects(19)	85.42	66.11	81.37	0.026 $p > 0.05$	0.019 $p > 0.05$	0.069 $p > 0.05$	0.001 $p > 0.05$

*Only 3 of 13 registry subjects had any college training, whicle almost all social subjects had. Therefore, 10 of the registry subjects were given the Personnel Test for Industry which has no total score, while the others were given the Wesman Personnel Classification test.[2]

TABLE A-55. MOTIVATION SCHEDULES IN TRAINING AND TESTING ON THE FOUR DEVICES FOR THE THREE SUBJECT GROUPS

Device	Group	Training	Testing
QuicKey	I	$1.00 for each reaction time less than 150 milliseconds	$1.50/pass (only 1 pass per testing session possible)
	II	$1.00 for each reaction time less than criterion set from previous training sessions	$0.50/pass
	III	No bonus	$0.50/pass
Complex-Reaction Tester	I	$5.00 for 4 passes/ 4 trials	$0.50/pass
	II	(Data disregarded due to a malfunction	
	III	$5.00 for 7 passes/ 8 trials (on two consecutive blocks) each training day	$0.25/pass(plus double bonus if all trials were passed)
Reaction Analyzer	II	$5.00 for 9 passes/ 10 trials each training day	$0.50/pass
	III	$5.00 for 19 passes/ 20 trials (on two consecutive blocks) each training day	$0.25/pass (plus double bonus if all trials were passed)
Phystester	I	$5.00 for 23 passes/25 trials each training day	$0.50/pass
	II	$5.00 for 23 passes/25 trials each training day	$0.50/pass
	III	$1.00 for 10 passes/12 trials at intermediate criterion $5.00 for 23 passes/24 trials on two consecutive blocks at final criterion	$0.50/pass (plus double bonus if all trials were passed)

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