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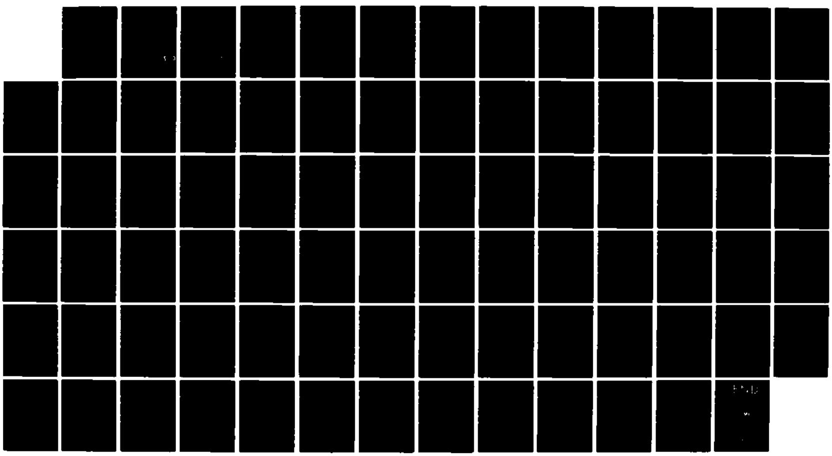

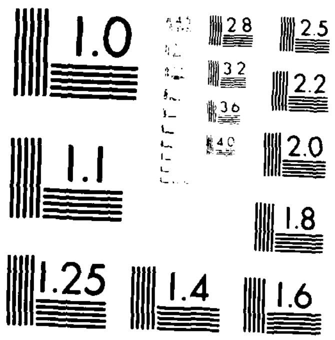

MICROCOPY RESOLUTION TEST CHART

THE MEASUREMENT OF HUMAN TIME ESTIMATING ABILITY USING A MODIFIED JERISON DEVICE

THESIS

Daniel C. Kinney
Captain, USAF

AFIT/GSO/ENG/84D-2

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THESIS

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
Air University
In Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Space Operations

Daniel C. Kinney, B.A.
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Preface

When I was first introduced to this topic for research, I was estatic that I might have the oppertunity to do work that would ultimatly be used in the U.S. Space Shuttle program. I felt the research was of significant value and I could see a clear link between it and my past experience with electronic hardware. I also felt that this research was an excellent oppertunity to work with, and learn from, some of the best Life Science professionals. My expectations were fully realized. The people I have delt with throughout this thesis have been of the highest caliber. I have learned a great deal from both my thesis committie and my sponsors at AFAMRL. The time spent on the bench designing, fabricating, and testing the electronics gave me an opportunity to forget the text books for a while and to sharpen other skills. Finally, the research was of such value that it did shape the course of the US space program in it's small way. The proof is in the fact that this experiment will be aboard a shuttle flight in early 1985. I owe my sincere thanks to Dr. Matthew Kabrisky and Lt. Colonel Joseph W. Coleman for agreeing to advise me through this thesis.

I would also like to thank the the labratory technicians at AFAMRL. MSgt Gregory Bathgate was a tremendous help to me during the prototype fabrication. I am especially grateful to Mr. Donald McColor for showing me the ropes and for the many hours of discussions on

implementation strategy. His guidance and the technicians willingness to help was a great asset to this research. The professionalism and technical competence displayed by these individuals and others in the laboratory was a key factor in the sucessful completion of this research.

I am also grateful to the many subjects who graciously gave of their time. I am intimately aware of the intense bordom associated with making repeated trials on the test unit. I hardly heard a single complaint. This research would not have been possible without your perserverance.

My deepest gratitude goes to my sponsors, Dr. Daniel Repperger and Mr. Charles Goodyear of AFAMRL. Their extensive time and effort in tootalige, monitoring, analysis, and guidance were tantamount in this work.

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List of Abbreviations

AFAMRL	Air Force Aerospace Medical Research Laboratory
CRT	Cathode Ray Tube
LED	Light Emitting Diode
STS	Space Transportation System

Abstract

Early in the Space Shuttle program , NASA became aware of a temporal distortion problem during the re-entry phase of each flight. This disorder was linked to space adaptation syndrome. The Air Force Aerospace Medical Research Laboratory (AFAMRL) was made responsible for developing research to find the source of these problems and methods to reduce their effects.

After design and fabrication of a prototype, a test procedure was established consisting of three experiments. The purpose of these experiments was to validate the test unit and to investigate modifications which could be incorporated into the shuttle experiment to optimize efficiency. Seven subjects participated in a pilot study where each performed three runs of 26 trials per run. From the analysis, results were comparable to those found in previous work. This coupled with an overall coefficient of variance of 15% was an indication of a rigorous experiment.

To analyze the effects of oral feedback, 18 subjects were tested in two groups. Group A did not receive feedback for the first three runs and did receive feedback for the last two runs. The opposite feedback sequence was provided to group B. Analysis revealed that a significant drop in relative error ($p \leq .05$) was experienced by group A subjects, once feedback was provided. For group B subjects the changes were insignificant ($p \leq .05$) when feedback was

removed. Thus a reference baseline is formed for the later case where the subject relative error does not change after feedback is removed.

Reducing the time required to perform each trial was the goal of the third experiment in which three window sizes were selected (0.8", 2.4", and 4.0") for investigation. Twelve subjects performed six runs of 45 trials each divided into three groups of 15. Each group of 15 trials was performed with one of the three window sizes. Analysis showed a decrease in relative error with a reduction in window size, especially for the longer times. Since the longer time was already underestimated, the reduction of relative error causes further underestimation. The reduction in relative error for the shorter times represents a minor improvement.

The results of this research indicate the modified Jerison device is accurate enough to properly monitor astronaut temporal acuity during shuttle missions. By introducing the astronauts to the tester with oral feedback and then denying it during flight, a true representation of time estimating ability will be measured without adaptation to feedback. Experiment efficiency was improved 203% by reducing window size from 4.0" to 0.8" without reducing data integrity.

THE MEASUREMENT OF HUMAN TIME ESTIMATING ABILITY USING A MODIFIED JERISON DEVICE

I. INTRODUCTION

BACKGROUND OF THE STUDY

Manned space flight has had considerable focus on experiments dealing with physiological adaptations to the space environment. Until the launch of Space Transportation System (STS) 2 (Space Shuttle Columbia) in November 1981, little was known of the effects of reentry. Earlier space journeys required little or no tasking of the astronauts once the reentry sequence was initiated. Space Shuttle flights differ considerably during reentry from earlier capsule reentries in that the shuttle astronauts have a great deal more to accomplish during the entire reentry phase. The shuttle astronauts have related that they experience a number of ill effects throughout the transition from the zero G space environment to the one G earth environment. These effects are manifested in the astronauts' sensation of drowsiness or a fatigue-like syndrome which degrades timely decision making capabilities. The astronauts complain of not having adequate time to accomplish critical tasks during reentry though the routine is practiced successfully on the ground before and after flight. This anomaly is known as time compression syndrome. The reasons for these symptoms may be because of changes in blood chemistry, changes in vestibular or proprioceptor inputs, boredom, cumulative fatigue, or any number of physiological or mental effects. Though the syndrome is common among STS astronauts, no measurements have been taken on their basic mental capabilities for processing information during the reentry phase of flight.

Previous research was conducted by another AFIT student, Captain Norman E. Michel, through the Air Force Aerospace Medical Research Laboratory (AFAMRL), Wright Patterson AFB, Ohio, to provide data on any changes in astronaut reaction times. The impetus of the research was provided by Dr. James Logan, one of the NASA physicians attending the astronauts. As a direct consequence of this first research, AFAMRL has been asked to proceed with research to reliably measure any changes in the astronaut's ability to estimate time passage. This would be accomplished through time estimation measurements by the astronauts before the launch, after launch in zero G, and during the reentry phase. Time estimation is the subject's ability to duplicate a time sequence (time frame) once a sample of the time frame has been presented to him.

AFAMRL has developed two separate and distinct devices, the simple and choice reaction time tester and the time estimation tester, and integrated them into a single package that will be carried on STS missions beginning in the spring of 1985. In addition to obtaining data for research relative to Capt. Michel's thesis, the unit records the subject's time estimation ability (TEA) using a visual stimulus. A prototype time estimation tester and associated readout device was used as the basic instrument of this research project and drove the final design of the integrated Reaction Time/Time Estimation Tester. Dr. Daniel Repperger (AFAMRL), Mr. Charles Goodyear, and Mr. Donald McCollor (AFAMRL/Ratheon) had responsibility for designing the machine and developing the experiment to measure the subject's time estimation ability. Dr. Clark Shingledecker, a psychologist with AFAMRL, provided his expertise in the development of the machine and the experiment.

Importance

The importance in these studies is found in the desires of the Air Force and NASA to improve the decision making capabilities of pilots and astronauts during high workloads and/or stress. The measurements of TEA through all phases of shuttle flight may provide insight into the causes and possible alleviation of the discussed difficulties.

STATEMENT OF THE PROBLEM

NASA requires study in the area of astronaut time perception and discrimination as a first step to discover the cause of, or compensate for, a number of undesirable effects of orbiter reentry. Measurements of this type have never been accomplished during STS missions. The Air Force desires an investigation into the time compression syndrome for insight into improving pilots' responses during high task, high stress phases of flight.

RESEARCH QUESTION

The significant questions to be answered in the research are:

- Whether the time estimation measuring device provides rigorous and consistently reliable measurements.
- Whether the initial configuration of the time estimation measuring device can be modified to improve operational capability without sacrificing data validity.
- Whether the device and experimental procedure are transferable to STS operations and, thus,
- Can an adequate data base be provided to NASA and the Air Force for later use.
- Can this technology/procedure be "spun off" into such uses as sobriety tests, IQ tests, and medical diagnostic tests.

SCOPE

The first objective of this research was to design and fabricate a variation of the Jerison time estimation device. This modified Jerison device has the requirement of being STS compatible; meaning it must be light weight, reliable, and totally self contained. To this end, a replacement for the massive and power hungry CRT was required. The prototype was used to determine if the modifications created any incongruencies with the original Jerison device. Chapter III describes a pilot study which was performed to help make this determination.

The second objective of the research was to determine if providing feedback aids the subject in improving his TEA. When this research began the decision whether or not to provide the astronauts with a readout of their estimated time had not been made. A definitive answer was needed for the question of whether feedback was of value before the extra effort was put forth to design and incorporate the feedback feature. Initial expectations, based on a small amount of data obtained during the construction and testing of the TEA test units, was that TEA would not improve with feedback even if the subject had never been tested before.

The final objective of the research was to tailor the experiment to fit the STS environment and astronaut workloads. Since space flight represents the most expensive flight time in the world, maximum effort was required to make the experiment as efficient as possible. During the pilot study concern developed as to whether the slower, more time consuming run speeds were required. An additional concern was whether the physical length of the visual stimulus could be reduced for all runs, and if so, by how much. If either or both of these two variations could be made without degradation of the results, substantial time savings would be realized. The saved time could then be used either to take more runs in the same allotted time, which would increase the reliability of the obtained data, or it could be given back to NASA to accomplish other tasks.

Methodology

Subjects for the feedback experiment (chapter IV) consisted of 18 healthy volunteers, all of whom were students of the Space Operations curriculum at AFIT. The subjects were divided into two groups of nine. TEA was measured in five runs of 26 trials per run (appendix B). One run per day was performed by each subject. Group A was not given feedback for the first three runs (days) and was given feedback for the last two runs. Group B was tested with the opposite feedback sequence. In an effort to reduce errors caused by factors external to this experiment, subjects were asked to refrain from things that were out of their ordinary daily routine throughout this experiment. This would include excessive drinking, all night study sessions, ect.. Each subject was asked to fill out a questionnaire before to each run. The purpose of the questionnaire was to help identify causes for outliers. Subjects were assigned a daily time slot, which remained the same for each run of the experiment. This was done to minimize the effects of circadian rhythms.

The window reduction experiment (chapter V) was conducted using 12 additional subjects from the AFIT student body and their spouses. None of the 12 had ever been tested in previous TEA experiments. A questionnaire was again required of each subject for each run (appendix C). Each run consisted of 45 trials divided into three sections of 15. Each section had a different window size which was determined by subject number and run number (table 1). For example, subject three was tested with sequence two for his fourth run. In that run, for his first 15 trials, only 1/5 of the total visible display was used. The second 15 trials were accomplished with the full display and the third 15 trials were done with 3/5 of the total visible display. Subjects were arbitrarily assigned a number which was used to identify them throughout the experiment and to determine the window size assignment for each run. Window sizes were manually selected by the investigator during the experiment.

For both the feedback experiment and the window reduction experiment, the TEA tester was placed on a table in front of the subject. The subject was allowed to position the tester in a location that was comfortable to him. No consideration was given dominant hand variations since the experiments require only a single simple hand movement and each subject was allowed to place the tester in any position that would accommodate his dominant hand. In the feedback experiment, the speed at which the visual stimulus traveled across the window was randomly selected out of five possible speeds. The speeds are expressed in terms of the times the traveling light is unseen or the "actual time" and were 20.0, 10.0, 5.0, 2.5, and 1.25 seconds. In the window reduction experiment the number of speeds were reduced to three; 8.0, 4.0, and 2.0 seconds. In all experiments, the subject initiated the stimulus and simultaneously selected a display speed by pressing a push button labelled "reset". The subject watched the traveling stimulus until it reached the end of its travel. He then judged when the stimulus would reach a marked location on the face of the tester by depressing

Table 1. Window Size Order

SUBJECT	RUN NUMBER 1	2	3	4	5	6
1	1	3	5	4	6	2
2	5	4	2	6	3	1
3	3	1	6	2	4	5
4	2	5	3	6	1	4
5	6	2	3	4	1	5
6	4	6	1	5	3	2
7	3	5	2	1	4	6
8	6	3	1	2	5	4
9	1	6	4	5	2	3
10	5	1	4	3	2	6
11	4	2	5	1	6	3
12	2	4	6	3	5	1

PATTERN		DISPLAY ORDER		
1	============>	1/5	3/5	1
2	============>	1/5	1	3/5
3	============>	3/5	1	1/5
4	============>	3/5	1/5	1
5	============>	1	1/5	3/5
6	============>	1	3/5	1/5

another push button labled "Respond". Subject error times were displayed on the readout device and recorded by the investigator along with the actual elapsed time. A detailed description of the TEA tester and readout device is found in appendix D.

Sequence of Presentation

Chapter II gives a brief review of the literature applicable to this study. Since the impetus for this work was previous work by Dr. Jerison of Wright Air Defense Center (WADC), a complete section is devoted to review of his efforts while another section sites other methods of measuring human time estimation.

Chapter III explains the pilot study that was first performed to verify the results obtained by Jerison. The pilot study design, methodology, and results are described. Chapter IV and Chapter V describe the feedback and window reduction experiments respectively from subject selection to results obtained in the experiments. The discussion of those results, the conclusions drawn, and recomendations for further study are found in Chapter VI.

II. LITERATURE REVIEW

The first thing that must be realized when discussing time estimation experiments is that the literature abounds with material in this topic area. Limited to a manageable number of references, the following is a synopsis of some of the most recent and significant sources. Time perception has been the topic of scientific investigation for at least 90 years (1:548) and to illustrate the extent of this work Zelkind and Sprug (2) cite nearly 1200 studies relevant to human time perception.

Jerison Time Estimation Method

Experiments relating to time perception can generally be grouped into three distinct categories delineating the methodology used in the experiment to measure human estimation of time passage (3:155). In the first of these categories, verbal, a time interval is presented to the subject and he is asked to estimate verbally its duration (the judgment) in terms of seconds and minutes. In the method of production, the subject is asked to delimit operatively an interval (the judgment) of a given duration as stated verbally by the experiment administrator. In the method of reproduction, the experiment administrator operatively delimits an interval and then asks the subject to reproduce operatively an interval (the judgment) of the same duration. One experiment that does not conveniently fit into any of the three above categories utilizes a moving dot display which travels from left to right at a constant speed (Jerison method). The dot disappears behind an opaque mask at some point in its travel. It is the task of the subject to respond when he predicts the dot will reappear (the judgment) at the other end of the mask (4:2)(fig 1).

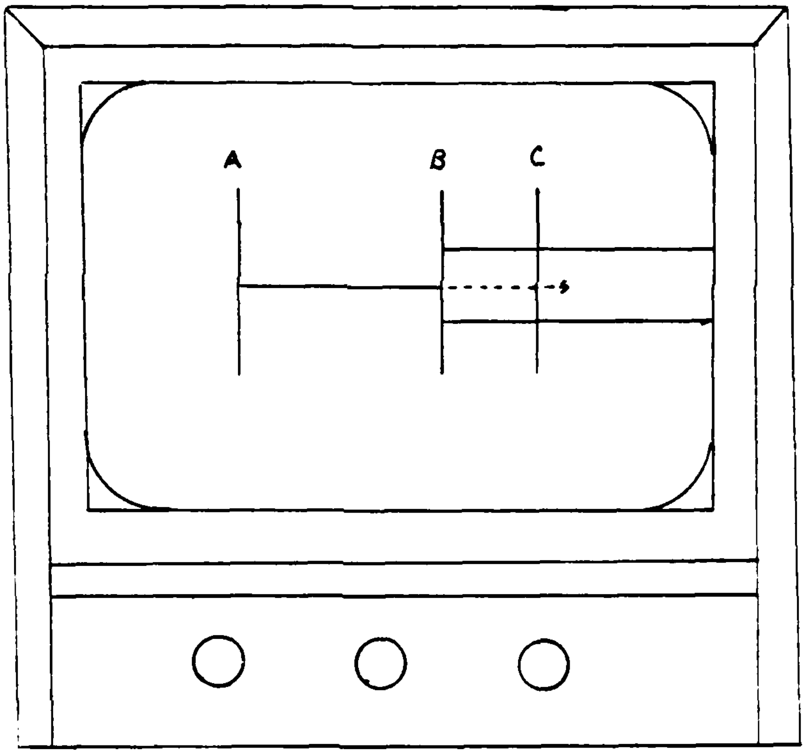

Figure 1. Jerison Display

Limited by technology in 1958, the Jerison experiments utilized a CRT (cathode ray tube) as a display and the opaque area was created by placing black masking tape on the face of the CRT. The traveling pip was displayed for four inches (point A to point B) and the judged interval was two and one half inches long (point B to point C). The rates selected for this experiment were .8, .4, .2, .1, and .05 inches per second which corresponded to a masked interval of 3.13, 6.25, 12.5, 25, and 50 seconds respectively. Response measurements were accurate to the nearest .001 minute (nearest 60 milliseconds).

The results of this experiment followed the classical results where the ratio of judged interval to correct interval (relative error) is greater than one for short intervals and is less than one for longer intervals (4:8). The typical result of a time judgment experiment is often summarized as indicating that short time intervals are overestimated and long time intervals underestimated and is often referred to as the regression effect (10:587). The masked interval at which the relative error is equal to unity is called the indifference interval (4:8).

General Time Estimation Research

Considerable discussion has been given, in the literature, to the nature of how humans perform the natural task of time perception. In an experiment by Poynter and Homa (1), a visual display is presented to the subject that tests the hypothesis that humans judge the passage of time by the number of discrete events that occur during the interval of concern. The display, a horizontal line of eight lights, was sequenced in a number of different patterns with each trial requiring the same amount of time to be accomplished. After two patterns were displayed, the subject was to select the pattern he judged to take longer though the time was the same for both. The data obtained from this experiment does support the theory of "filled" time or time estimation based on the principal of event passage.

Another theory relating to how humans accomplish time passage estimates is presented by Rousseau, Poirier, and Lemyre (5). In general, discrimination models assume that the encoding of temporal extent is performed by a central timekeeper common to both visual a well as auditory stimulus. The purpose of this experiment was to show the error of assuming a central clock mechanism. The authors postulate the existence of at least two separate clocks, one for each sensory organ, and support this position with the data obtained from this experiment. The verbal method of estimation was employed in this experiment. Elapsed time was judged by the subjects to be one of four long intervals or one of four short intervals. The subjects response was 'long' or 'short'. Initial and terminal stimulus of the time interval was a light flash (L) or an audible tone (T). All possible combinations (TT,LL,TL,LT) were used on each time interval. The data obtained supported the existence of multiple noncoherent internal clocks in that the light-light (LL) stimulus provided data commensurate with past work and the tone-tone (TT) stimulus provided more accurate and less variable data than the LL stimulus which is also commensurate with past work. The discriminating factor in this experiment was the data obtained from the LT and TL stimulus. The two sets of data agreed with each other and were both significantly less accurate than either the LL or TT stimulus situations. Thus intermodal time estimation (aural to visual or visual to aural) has inherent inaccuracies built in due to the possible existence of multiple clocks.

On the other hand, Rule, Mahon, and Curtis (8) constructed an experiment designed to refute a parallel clock model of human time perception presented by Eisler (9) in which the durations of serially presented intervals are monitored by two sensory registers operating simultaneously. One register monitors the total duration from the onset of the first interval to the offset of the second, and the other register begins at the onset of a second interval and continues to monitor duration until both intervals terminate (8:569). The Rule et al. experiment established seven time intervals from .5 to 10 seconds and presented the subjects a pair of these intervals to judge which was longer. The pair of time intervals were presented one after the other for some subjects (sequentially) and were presented at the same time with a common offset. The data obtained does not dispell Eisler's parallel clock model but it provides no evidence to support it.

As the Rosseau et al. (5) experiment explains, the majority of time estimation experiments assume a single internal master clock. Halpern and Darwin (6) imply the same assumption in their experiment where they attempted to explain human time estimation in terms of rhythmic events. They proposed a theory that time estimation is based on an internal clock that counts intervals such as the intervals between the beat of musical scores. The experiment consisted of subjects listening to a series of four clicks, the first three of which were of equal temporal spacing. The fourth click was either early or late relative to the correct time interval and the subject was required to report his judgment of the placement of the fourth click. As a side note to this experiment, the data show no tendency for musically inclined individuals to have better rhythmic judgment than non musically inclined individuals. This would suggest that the internal clocking mechanism is innate.

One theme that appears throughout the literature is that short intervals of elapsed time are generally overestimated and long intervals are generally underestimated (7). This phenomenon, known as regression effect, (10:587) has been well documented for intervals ranging from a few hundred milliseconds through approximately 30 seconds (2:585). Ferguson and Martin (10) extended the research to periods of months and years and concluded that items less than 9-12 months old were overestimated and items over 12 months old tended to be judged accurately with some tendency toward underestimation (2:591). Long intervals of the sort judged in this experiment could not, of course, be generated directly in a laboratory, but appropriate data was obtained by asking subjects to judge the amount of time that had elapsed since the occurrence of some event. The events were selected from within the cognizant lifetime of the subjects.

CONCLUSIONS

Of the methodologies researched above, the Jerison (4) method of time estimation measurement seems the most appropriate for a number of reasons not least of which was the fact that with state of the art technology, a small package could be constructed to contain all the necessary equipment to implement this method. Other methodologies such as those of Rule et al. (8) or Halpern and Darwin (6) could have just as easily been packaged for space flight but the data would have required a great deal more analysis and may have been of marginal value for the purpose of this experiment. A further reason for selection of the Jerison method is the inability to intentionally or unintentionally cheat by counting or tapping. This aspect of time estimation research makes many experiment methodologies suspect and could render some useless.

III. Pilot Study

A pilot study was performed before implementing research on experiment optimization. the purpose of the pilot study was to compare the results of the modified Jerison tester against results obtained from the original Jerison experiments. Digital technology available today permits us to reduce the hardware into a small package, but, at the same time, it creates a departure from one of the original premises. In the original experiment the traveling pip on the face of the CRT was a continuous, constant movement, where as the digital technology necessitated the movement of the pip to be in small, discrete jumps. The time interval between jumps is constant throughout the run, resulting in an average speed that remains constant. For this reason it was necessary to design a study to determine if the effects of the new technology compromised the experimental design. Because of the limited allotted time available during actual STS missions, design efficiency was a prime goal. As such, the the pilot study incorporated a slightly modified display scenario, details of which follow in this chapter. It was important that these changes did not change the general results expected. The results of the pilot study are discussed in this chapter.

Methodology

Seven subjects were tested in a reserved classroom in the AFIT School of Engineering (Bldg 640). Five of the subjects were students of the Space Operations Program and two were from AFAMRL. All subjects were briefed on the nature of the STS problem and the study. In addition, all subjects were asked to read a synopsis (appendix A) before the first test to further assure that they all fully understood what was expected of them. All subjects were males between the ages of 28 to 42.

The modified Jerison device differs from the original Jerison device in that the traveling pip (visual stimulus) moves in 20 incremental steps across the four inch display area instead of being continuous, and in that the masked portion is two inches long instead of two and a half as in the original Jerison device. Additionally, the speed of the traveling pip was changed in order to expedite the test. The new actual times were 20.0, 10.0, 5.0, and 2.5 seconds (a fifth actual time of 1.25 seconds, which was also available, was not used in the pilot study because of a fault in the device). The actual times used in the original Jerison study were 50.0, 25.0, 12.5, 7.25, and 3.13 seconds.

Each subject was tested on three separate days with 25 trials each day. Trial speeds were randomly selected from the four available (20.0, 10.0, 5.0, and 2.5 seconds actual times). Trial speed and subject error was recorded by the investigator on the questionnaire form that subjects had filled in before each test session (appendix B). The times were transferred to punch cards, entered into a file on the

CDC 6600 computer, and analyzed using the available Statistical Analysis System (SAS) package on the computer.

Results

Figure 2 shows the mean relative error for each of the four actual times used in this study. A perfect estimate occurs when the dependent variable equals 1.0. Clearly the subject tended to underestimate long times and overestimate short times. It should be noted that the cross over (indifference interval) occurrs at approximately 16 seconds. This implies that humans are best suited to estimate time frames of approximately 16 seconds when the range of actual times is between 5.0 and 20.0 seconds. The coefficient of variation (cv) for the data displayed in figure 2 is illustrated in figure 3. Note the mean values of cv = (standard deviation)/(mean) is less than 15%. The variable cv is a good measure of a consistent, repeatable experimental measurement. The coefficient of variation does not seem to vary greatly over the different time estimation values. Figures 4 and 5 display relative error and coefficient of variation vs. run number respectively. The abscissa in these two figures represent an average across all four time periods. The purpose of these two plots is to investigate learning from the first run to subsequent runs. A decrease in relative error would indicate learning. In agreement with the Jerison paper, it appears that there is no learning that we can identify, and subjects might

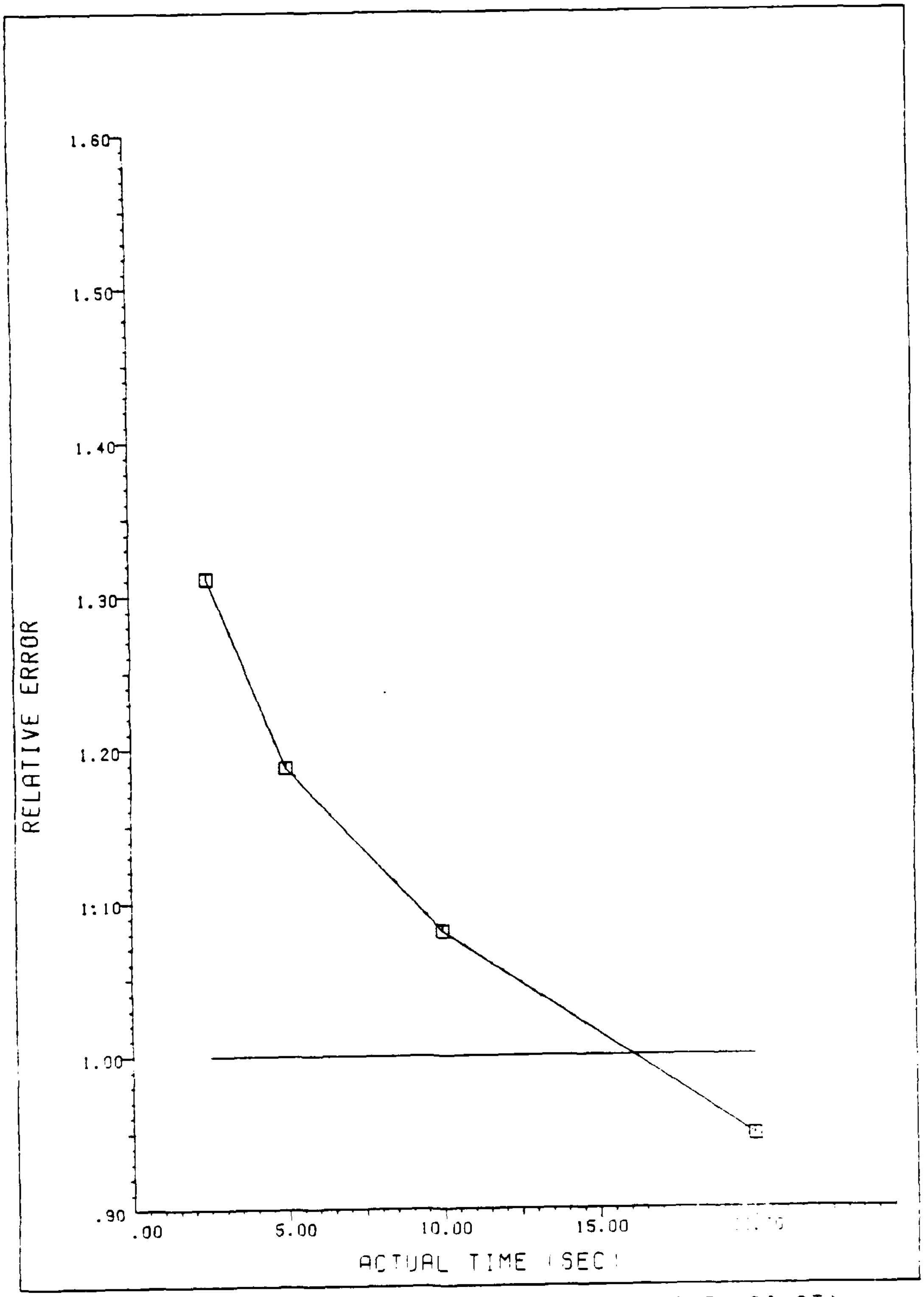

FIGURE 2. RELATIVE ERROR VS. ACTUAL TIME (PILOT)

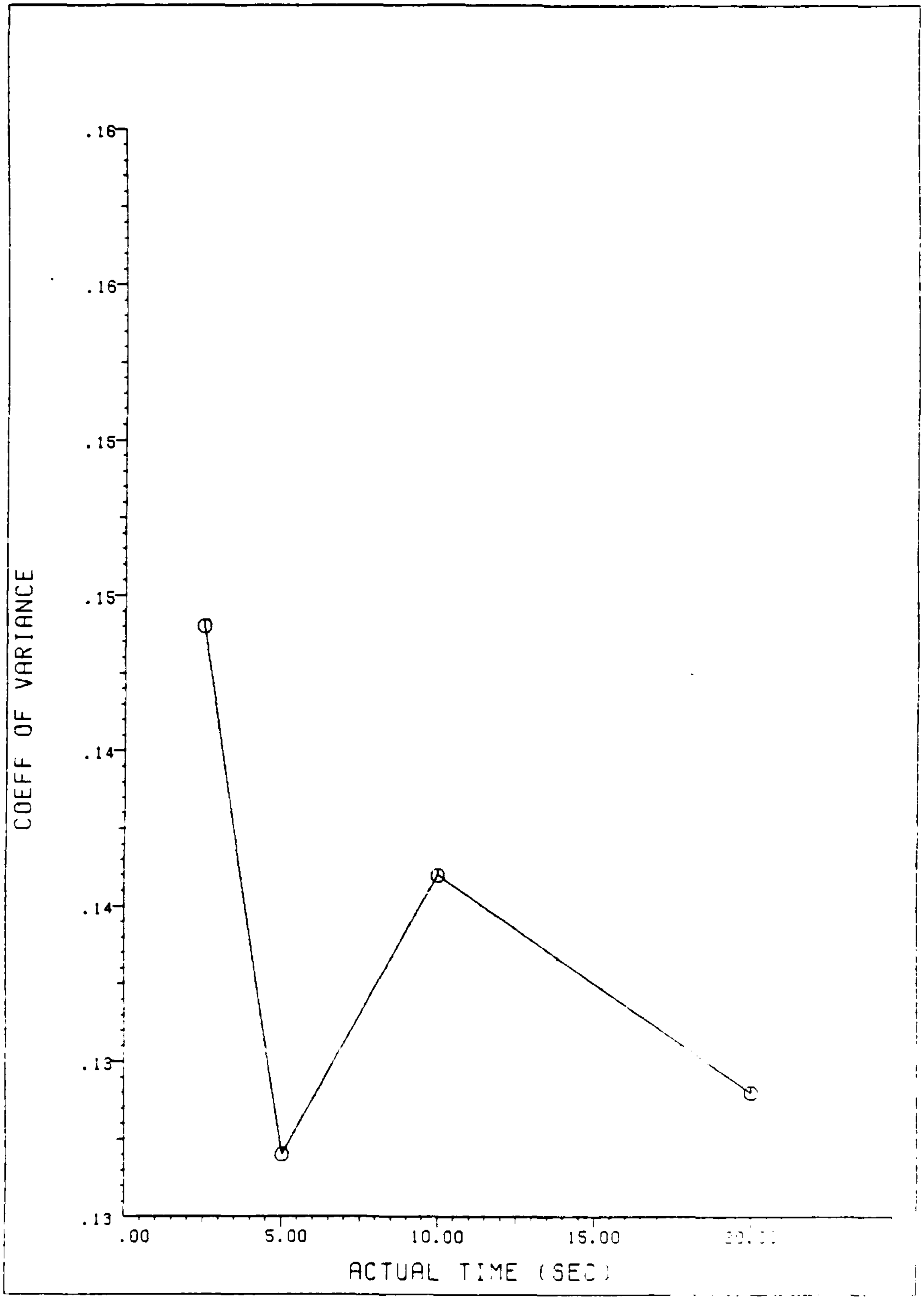

FIGURE 3. COEFF OF VARIANCE VS. ACTUAL [illegible]

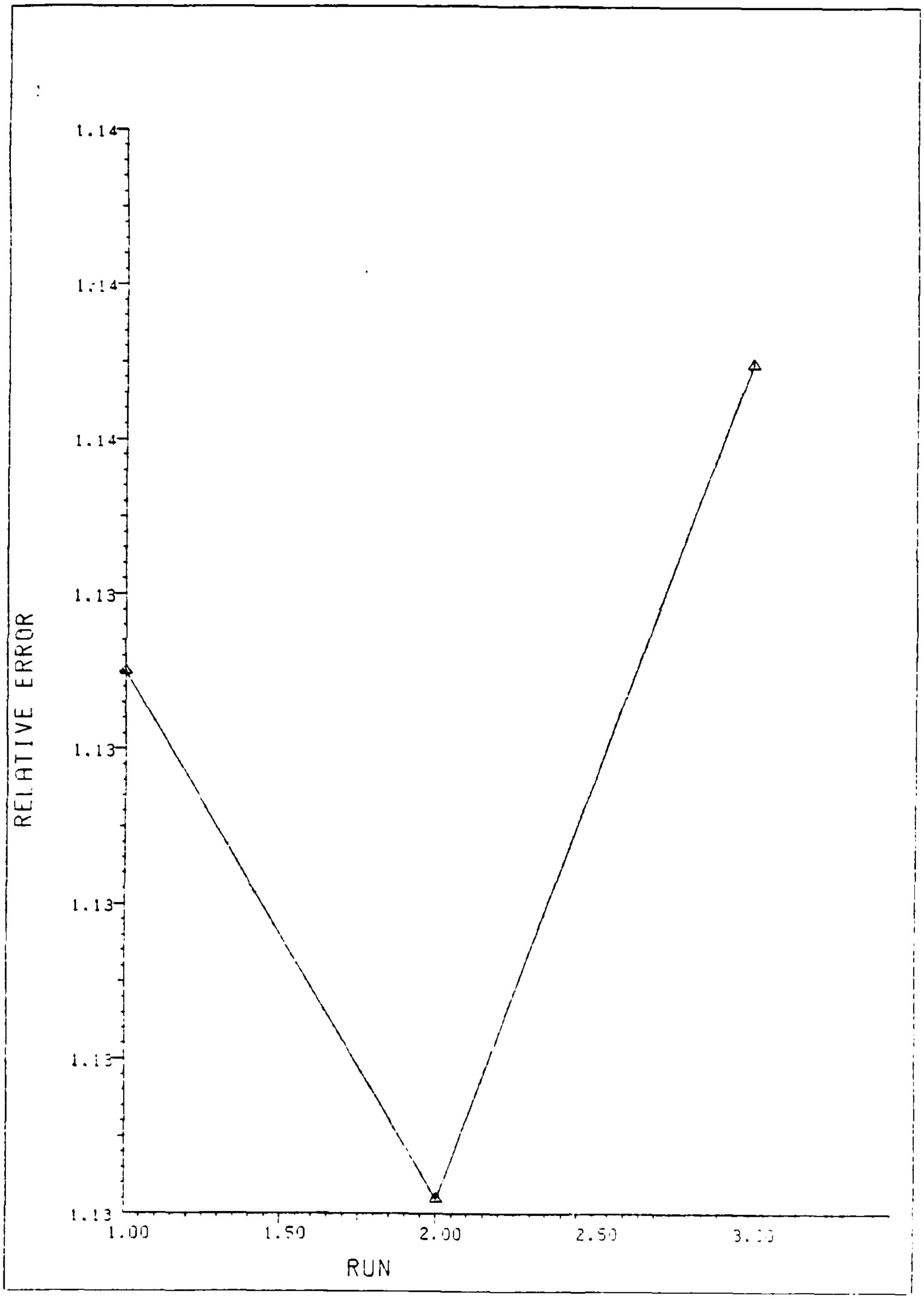

FIGURE 4. RELATIVE ERROR VS. RUN (PILOT STUDY)

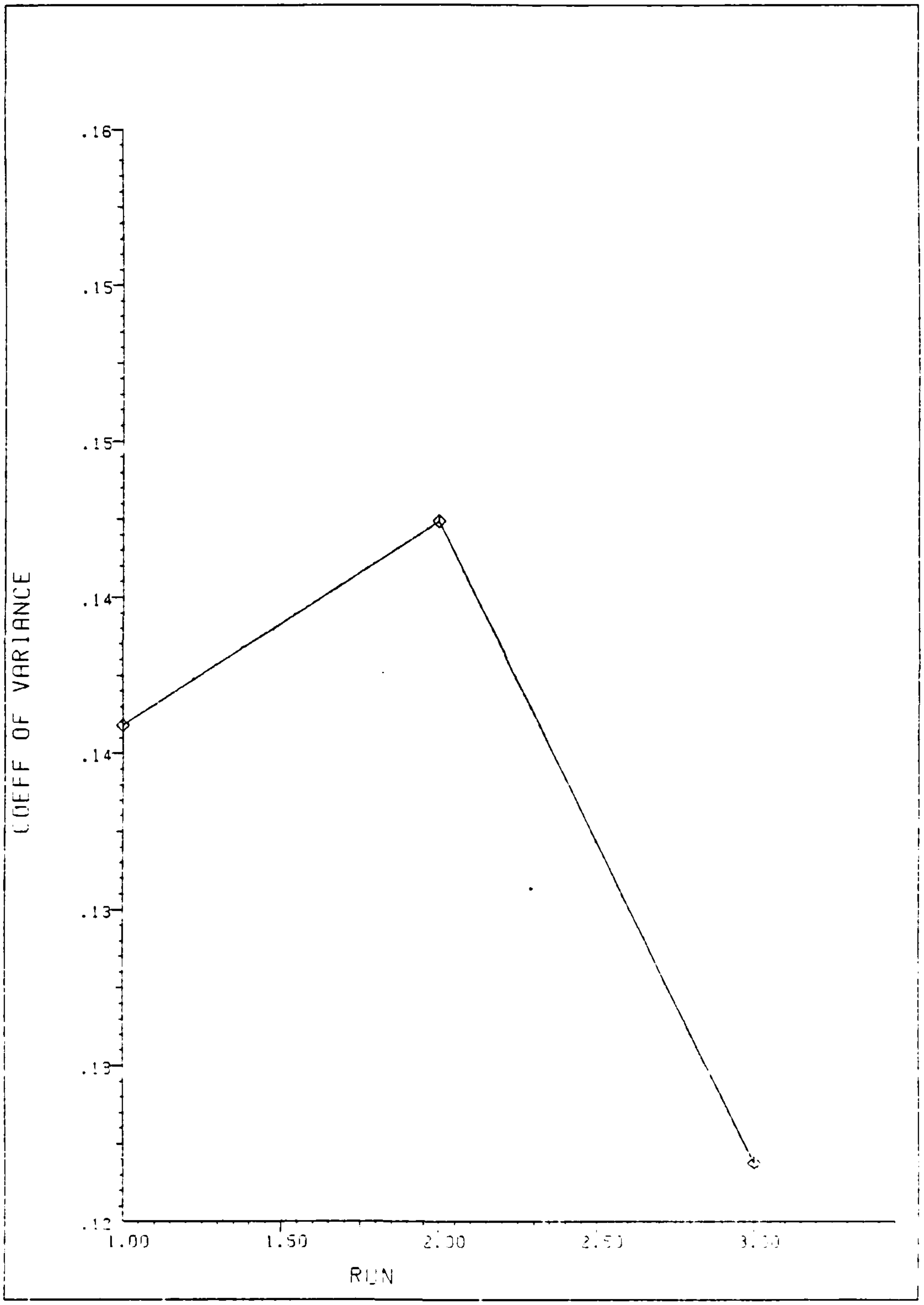

FIGURE 5. COEFFICIENT OF VARIANCE VS. RUN (PILOT

actually get worse in repeated runs. This increase in relative error might be be due to subjects being anxious the first run or two. No apparent change in variation can be seen in figure 5, further suggesting no learning.

DISCUSSION

The purpose of this pilot study was to duplicate the original Jerison results using a new system of visual display, ie. LED vs CRT. The results clearly indicate similarities between the two while at the same time indicating one major difference. The slope of the curve in figure 2 is in agreement with that of the Jerison study, ie. shorter intervals are over estimated and longer intervals are under estimated. The coefficient of variation of 15% is less than the 20% generally used by AFAMRL as the guide of a consistent, repeatable experiment. The results shown in figures 4 and 5 indicate an absence of learning from run to run which is also in agreement with the Jerison study. The one significant difference between the two studies is the indifference interval. The Jerison paper found it to be approximately 48 seconds while this study determined the crossover from under estimation to over estimation to be 32 seconds earlier. This phenomenon is well documented in the literature (10:587) and is therefore to be expected. Ferguson et.al and others have suggested that this effect is dependent on the range of stimulus durations presented. Within these experiments, the range of stimulus duration has clearly been the factor in establishing the indifference interval.

IV. The Effects of Feedback on Human Time Estimation

This chapter explains the implementation of the experimental procedure by which the effects of feedback were measured. It is the first such experiment known to the author and his sponsors at AFAMRL. In this chapter, subject selection, test methods, and results are discussed.

Subject Selection

Subject participation was individually solicited from a new class of AFIT students enrolled in the Graduate Space Operations program (GSO-85D). Individuals were contacted sequentially from an alphabetical roster until 18 subjects agreed to participate. Each subject was briefed on the test procedure, what would be required of him, and assigned a 15 minute daily time slot that would not interfere with his individual school schedule. None of the subjects had participated in the pilot study. Subjects were arbitrarily divided into two groups (A and B) of nine subjects each. Of the 18 participants, 15 completed the experiment satisfactorily; seven in group A and eight in group B. The final population consisted of one female and 14 male subjects between 26 and 35 years of age. Fourteen of the subjects were Air Force officers and one male subject was a civilian Defense contractor employee. No training or practice trials were permitted for any subject.

Methodology

The experiment was initially designed to span five consecutive days. Subjects in group A did not receive feedback for the first three days and did receive feedback for the last two. Group B received feedback the first three days and did not the last two. It was important not to have a break anywhere in the schedule but most important between the third and fourth days. Thus subjects were scheduled for five consecutive weekdays. This was done to eliminate any unwanted change or shift in data when subjects went from initial feedback status to terminal feedback status. If changes were detected, they should be largely due to the change in status. To further assure reliable data, subjects were tested at the same time each day to minimize the effects of cicadian rhythms.

Subjects required approximately 11 minutes per run of 26 trials and another four minutes to fill out the questionnaire. The first subject began each day at 7:00 am with the subsequent 17 subjects beginning at 15 minute intervals throughout the day. The last subject began testing at 4:15 pm.

As in the pilot study, subjects were permitted to place the test unit in any position which accommodated their dominant hand. When the subject was ready, he initiated each trial by pressing the reset button. This would randomly select one of five display speeds which correspond to the five intervals to be estimated (actual time of 1.250, 2.500, 5.000, 10.000, and 20.000 seconds). After each trial the investigator recorded the display speed and the subjects error from the readout device, and provided the subject feedback when appropriate. The investigator then gave an indication to the subject to proceed when he was ready. Throughout this study the full display was used which consisted of 4" of visible light travel and 2" of masked travel.

Results

The 18 subjects provided 2340 data points (trials) of which 1560 were used in the final analysis. After the first day of testing an unstable condition was found to exist within the test unit. The corrections were made to the equipment and all of the first days data (468 trials) were disregarded. As the week progressed, three subjects encountered unexpected schedule conflicts. These subjects continued the experiment by taking two runs on the same day to make up for missed days. During the analysis close attention was paid to the data points from these three subjects. Because of excessive outliers, all trials from these three subjects (312 trials) were disregarded reducing the data point count to 1560. The final population consisted of 15 subjects, seven in group A and eight in group B, with each participating two valid runs before feedback status change and then another two valid runs after feedback status change. The purpose of the analysis was to determine the following:

- The significance of the change from run 3 to run 4 for each group. This was the point where group A went from no feedback to feedback and group B went from feedback to no feedback.

- The significance of the difference between the groups, for each actual time, at run 5.

- The significance of the difference between the actual time at run 5 for each group.

- The actual time for each group, estimated from the means at run 5, at which one would expect the best estimate (relative error = 1.0).

To ensure that the TEA tester was a reliable measure of repeated trials, an overall coefficient of variation (cv) was determined. To do this, the cv for each subject, actual time and run was determined and then averaged to get one mean cv for each subject. The cv mean and standard deviation over all subjects was 11.4% ± 3.0%. This value is less than the 20% cv used as an upper limit of acceptability in past experiments at the AFAMRL laboratory. The raw data used in the analysis was the mean relative error for each subject, actual time and run.

The percent change from run 3 to run 4 was calculated for each subject and actual time. T-tests and the Wilcoxon signed rank test (this test does not depend on the data being normally distributed) were performed, for each group, to determine the significance of the changes. In all cases, the null hypothesis Ho: change = 0, was tested against the alternative hypothesis Ha: change $\neq$ 0. Since the results were similar for the T-tests and the Wilcoxon, only the results of the T-tests are shown in Table 2.

Table 2. Percent Change In Relative Error From Run 3 to Run 4

Actual Time	Number of Subjects	Mean	Standard Deviation	T Statistic	Prob > Abs(T)
----------GROUP A----------					
1.25	7	-19.73	15.36	-3.40	0.0145
2.50	7	-17.17	10.64	-4.27	0.0053
5.00	7	-14.33	10.93	-3.47	0.0133
10.00	7	-13.05	9.02	-3.82	0.0087
20.00	7	-11.38	12.01	-2.51	0.0460

Actual Time	Number of Subjects	Mean	Standard Deviation	T Statistic	Prob > Abs(T)
----------GROUP B----------					
1.25	8	6.25	8.49	2.08	0.0757
2.50	8	-2.14	11.45	-0.53	0.6140
5.00	8	-1.08	7.99	-0.38	0.7137
10.00	8	5.70	11.74	1.37	0.2118
20.00	8	-3.23	4.56	-2.01	0.0849

In group A, for all actual times, there was a significant drop from run 3 to run 4 ($p \leq .05$), when feedback was given. For 1.25, 2.50, 5.00, and 10.00 seconds, this drop resulted in a better estimate, but for 20.00 seconds the result was going from overestimation to underestimation (figure 6). In group B, the changes were insignificant for

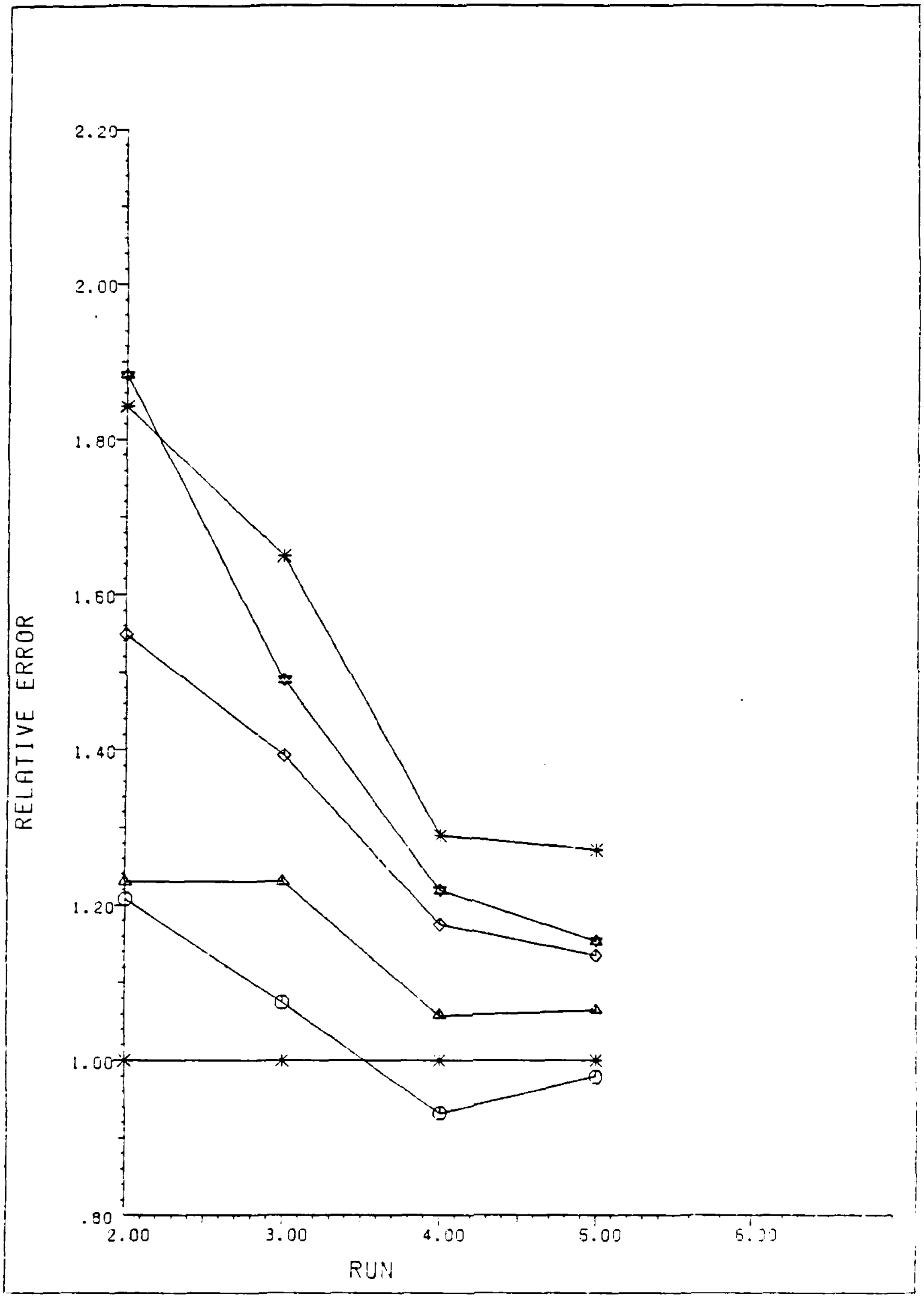

FIGURE 5. GROUP A TEST OF FEEDBACK

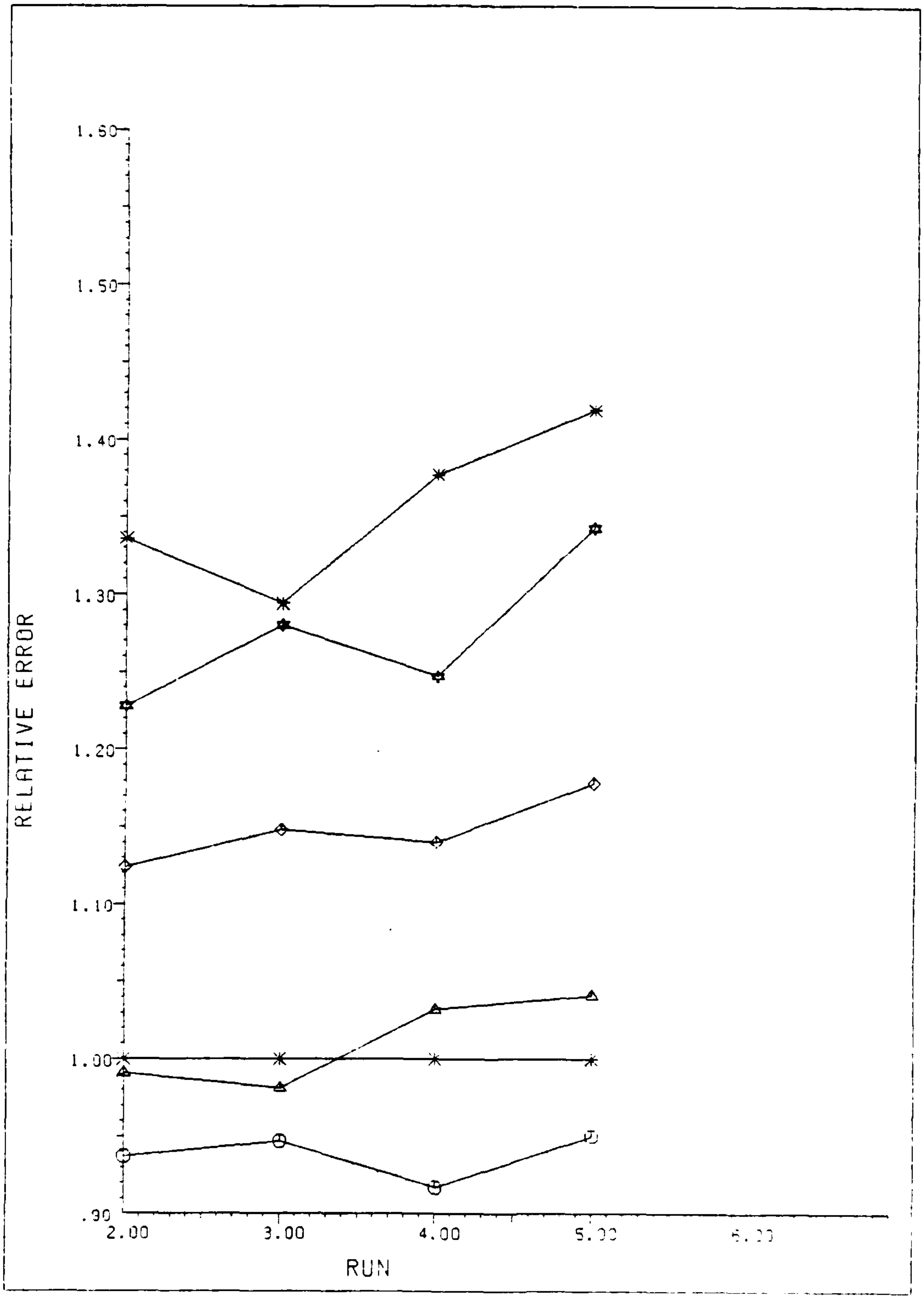

FIGURE 7. GROUP B TEST OF FEEDBACK

all actual times ($p>.05$), when feedback was taken away (figure 7).

It Should be again noted that it is assumed any change from run 3 to run 4 is due only to changes in feedback. This assumption is partially supported by previous experiments on a similar box (another prototype TEA tester that may eventually be used on the shuttle) where it was found that only two runs are necessary to familiarize a subject with the task.

The mean relative error for each subject and actual time was used in the analysis of differences between the groups for run 5. T-tests and Wilcoxon rank sum test were performed, at each actual time, to determine the significance of differences between the groups. In all cases, the null hypothesis Ho: group A = group B, was tested against the alternative hypothesis Ha: group A $\neq$ group B. It was desired to analyze each actual time separately, therefore, an analysis of variance using all actual times together was not performed. Since the results of the T-tests and the Wilcoxon were similar, only the results of the T-tests are shown in Table 3. Recall that for run 5 group A has feedback and group B does not.

No significant differences were found between the groups ($p>.05$). However, means indicate that for 1.250 and 2.500 seconds the absence of feedback results in a greater overestimation, while at 5.000, 10.000, and 20.000 seconds feedback has no effect.

Table 3. Comparison of Groups A and B at Run=5 For Each Actual Time

Variable: Relative Error

Group	N	Mean	Std Dev	Std Error	Minimum	Maximum	Variances	T	DF	Prob >¶T¶
Actual Time = 1.250										
A	7	1.271	0.315	0.119	0.952	1.769	Unequal	-0.8850	12.9	0.3924
B	8	1.419	0.331	0.117	1.005	2.057	Equal	-0.8817	13.0	0.3939
Actual Time = 2.500										
A	7	1.154	0.155	0.059	1.000	1.424	Unequal	-1.2886	9.5	0.2281
B	8	1.343	0.380	0.135	0.902	2.090	Equal	-1.2243	13.0	0.2426
Actual Time = 5.000										
A	7	1.135	0.091	0.034	1.012	1.253	Unequal	-0.5712	10.3	0.5801
B	8	1.178	0.191	0.067	1.023	1.582	Equal	-0.5461	13.0	0.5943
Actual Time = 10.000										
A	7	1.065	0.079	0.030	0.976	1.163	Unequal	0.5635	12.9	0.5828
B	8	1.041	0.082	0.029	0.945	1.156	Equal	0.5618	13.0	0.5838
Actual Time = 20.000										
A	7	0.979	0.057	0.022	0.897	1.057	Unequal	0.8754	13.0	0.3973
B	8	0.950	0.069	0.025	0.804	1.023	Equal	0.8635	13.0	0.4035

The mean relative error for each subject and actual time was used in the analysis of the differences between the actual times at run 5. Each group was analyzed separately to see if the differences between the actual times were similar for both groups. An analysis of variance was performed using subject and actual time as the factors. F-tests determined a significant difference between the actual times for both groups (group A p-value = .0197, group B p-value = .0010). To determine which actual times were different, a Bonferroni multiple comparison was performed on the means using a per comparison error level of .05. The results are as follows:

Table 4. Bonferroni Multiple Comparison

Group A

Actual Time	1.25	2.50	5	10	20
Mean	1.272	1.154	1.135	1.065	0.979
	———	———	———		
		———	———	———	
			———	———	———

Group B

Actual Time	1.25	2.50	5	10	20
Mean	1.419	1.343	1.178	1.041	0.950
	———	———			
		———	———		
			———	———	
				———	———

Means connected by the same lines are not significantly different.

Using the overall means for each actual time, an exponential curve was estimated, for each group, using non-linear least squares procedures to estimate actual time when the relative error is 1.0. An exponential curve was used based on observation of these means (see figures 8 and 9), and from the R squared values, the estimated curves fit the data well. The estimated curves are as follows:

group A
relative error = 0.9683 + 0.3278 * EXP(-0.1424*actual time)
R squared = 0.9344

group B
relative error = 0.9321 + 0.6152 * EXP(-0.1754*actual time)
R squared = 0.9977

Using the estimated curves, the actual time that would be best estimated by each group were 16.4 seconds for group A and 12.6 seconds for group B.

Conclusions

Subjects tend to overestimate shorter times (less than 10 seconds) and underestimate longer times (20 seconds) because of the regression effect. When a subject is exposed to feedback after having no feedback, the subject will tend to reduce their relative error. To the shorter times (less than 16 seconds) this represents an improvement in TEA but for the longer times (longer than 16 seconds) this represents a decrease in TEA since the longer times were already underestimated. For subjects having experienced both feedback and no feedback, having no feedback tends to

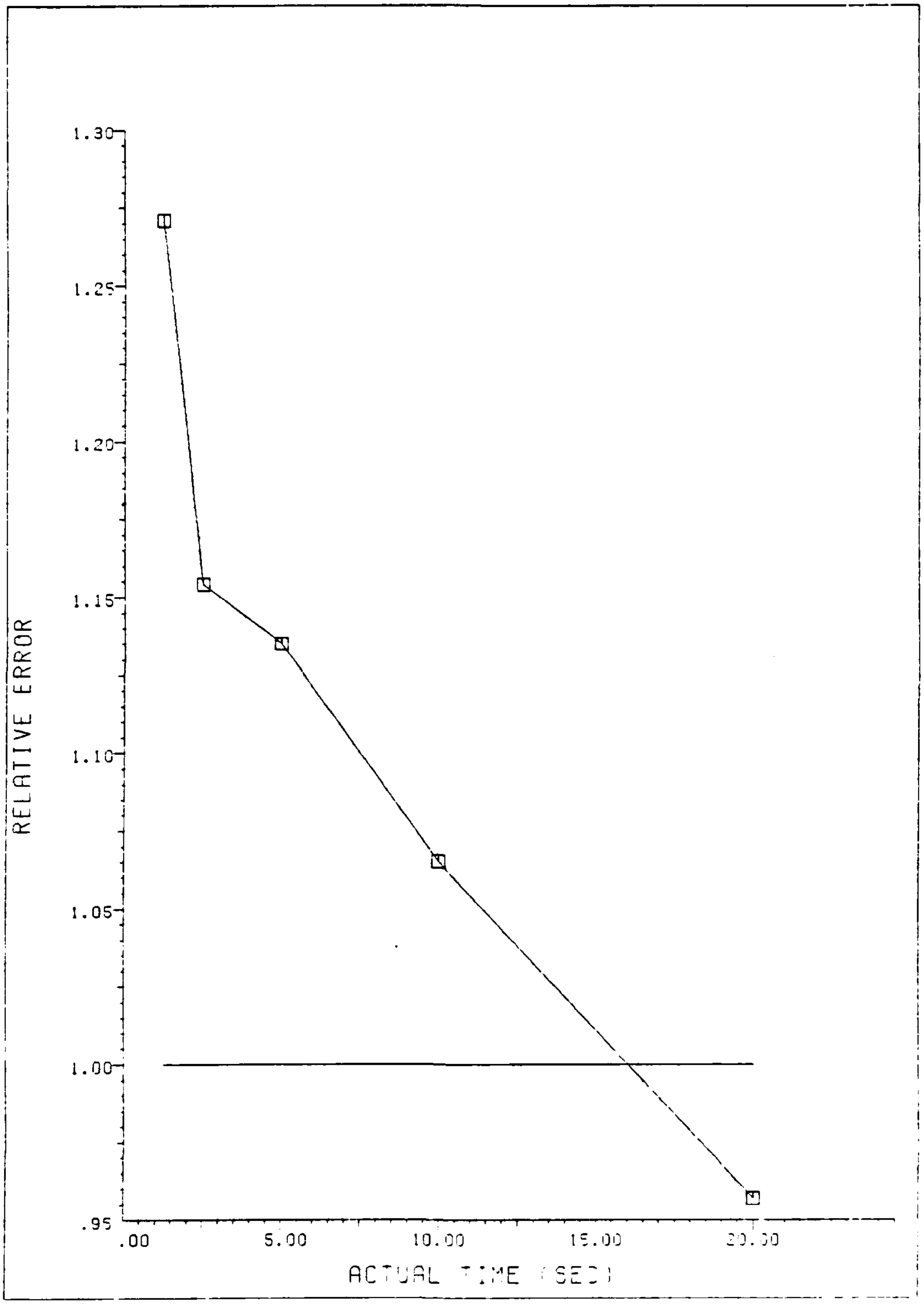

FIGURE 8. GROUP A RELATIVE ERROR VS. ACTUAL TIME

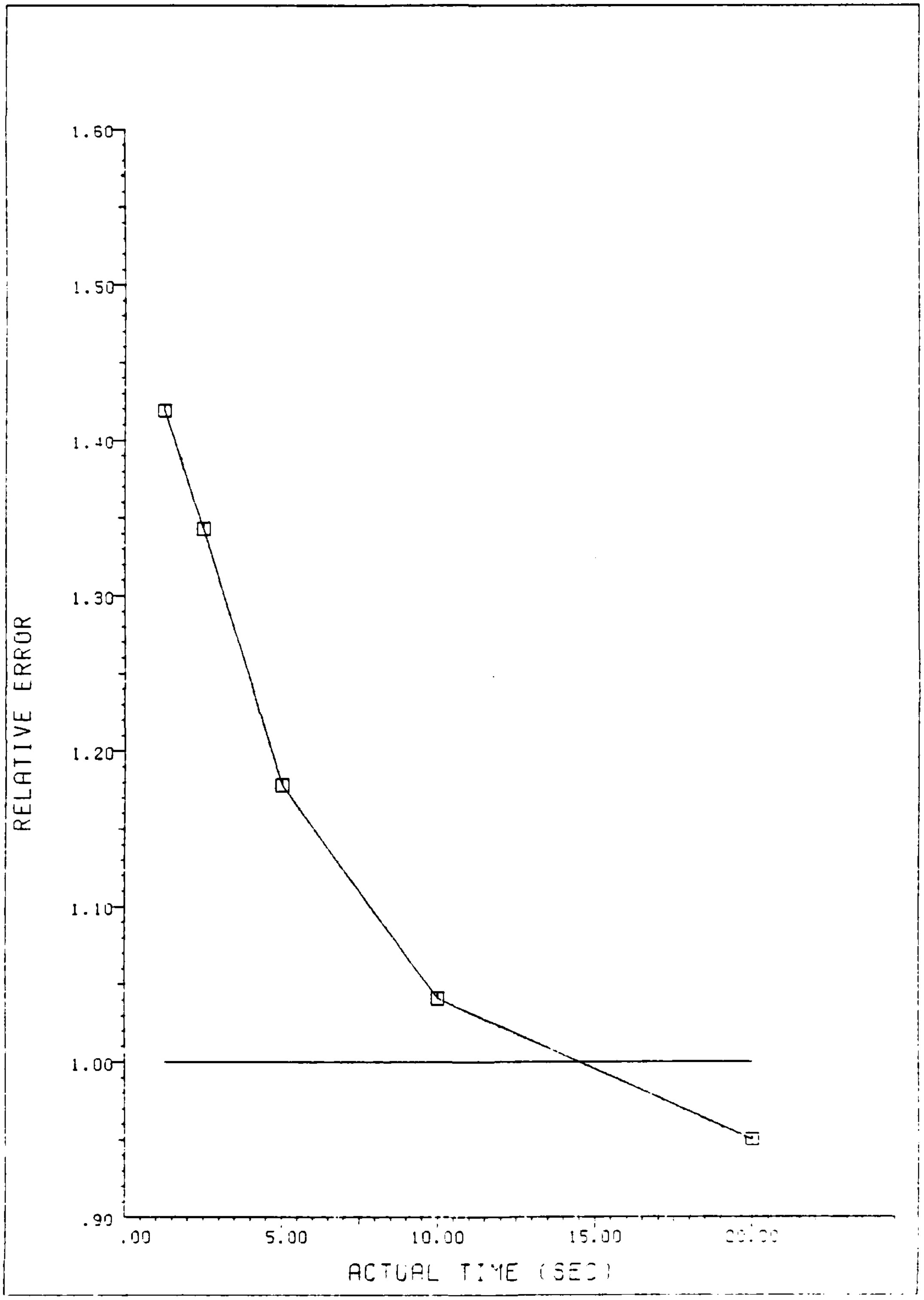

FIGURE 9. GROUP B RELATIVE ERROR VS. ACTUAL TIME

have an effect on increasing the overestimation at 1.25 and 2.5 seconds but having no effect at 5,10, and 20 seconds. Thus, once feedback has been given to a subject, he tends to maintain the same levels of relative error at the longer actual times. The estimated actual times at which the relative error = 1.0 was 12.6 seconds without feedback and 16.4 seconds with feedback.

V. Window Reduction Study

This chapter explains the implementation of a test to determine the effects of reducing the dimension of the visible portion of the traveling light emitting diode (LED) display (the window). The results of this research will be immediately used to guide the National Aeronautics and Space Administration (NASA) scientists in selecting an optimum window size for the shuttle borne experimental device. Since the shuttle experiment is software controlled, changes in window size, stimulus speed, and actual time (masked dimension) can be readily made at any time. The goal of any such changes in window size is conservation of astronaut time while maintaining data integrity.

Subject Selection

Remaining members of both the GSO-84D and GSO-85D classes, who had not yet had the opportunity to participate in any o: the two previous studies, were asked if they and/or their spouses were willing to volunteer some time. Subjects were not difficult to obtain since a strict time schedule was not required in this study. Subjects were assured session scheduling would be liberal and totally at their convenience. Additionally, the requirement to test each session at the same location was lifted. This added to the ease of obtaining subjects since sessions could be scheduled at locations convenient to all subjects.

Twelve subjects were used for this study of which four were male Air Force members and eight were female spouses of Air Force members. Subjects were tested on three separate days over a two week period. Two runs of 45 trials each were conducted each day with a ten to fifteen minute break between each run. The breaks were included to reduce errors caused by fatigue. Each run took about fifteen minutes to complete. Total session time, including equipment set up time, two runs, break, and equipment tear down time, was about 50 minutes. The first run of 45 trials was considered training time and was not used in the analysis of the data.

Methodology

Each subject performed six runs of 45 trials using estimated times (actual times) of two, four, and eight seconds. As in the past studies, the actual times were randomly selected by the subject automatically when he initiated a trial. The 45 trials were performed in groups of 15 each with each group using a different window length. The window lengths used in this experiment follow:

Actual	Portion of Full
4.00"	Full
2.40"	3/5
0.80"	1/5

The order in which the three groups were performed was randomized both within subjects (from one run to the next) and between subjects. Specific attention was paid to assure that subjects would not start any two consecutive runs with the same window size. Table 1. is presented here again to show how the window presentation order was randomized.

Table 1. Window Size Order

SUBJECT	RUN NUMBER 1	2	3	4	5	6
1	1	3	5	4	6	2
2	5	4	2	6	3	1
3	3	1	6	2	4	5
4	2	5	3	6	1	4
5	6	2	3	4	1	5
6	4	6	1	5	3	2
7	3	5	2	1	4	6
8	6	3	1	2	5	4
9	1	6	4	5	2	3
10	5	1	4	3	2	6
11	4	2	5	1	6	3
12	2	4	6	3	5	1

PATTERN		DISPLAY ORDER		
1	============>	1/5	3/5	1
2	============>	1/5	1	3/5
3	============>	3/5	1	1/5
4	============>	3/5	1/5	1
5	============>	1	1/5	3/5
6	============>	1	3/5	1/5

As an example, subject three was tested using pattern five on his sixth run. The full window was used for the first fifteen trials, 1/5 of the window was used for the second fifteen trials, and 3/5 of the window was used for the remaining trials.

Results

The 12 subjects provided 3240 data points (trials) over the six runs. The first run of each subject was considered as training and disregarded leaving 2700 data points. The same hardware, with modifications to accommodate the use of only three speeds, different speeds, and selectable window size, used in the pilot study and feedback study was used for this experiment. The statistical package used previously was used for the analysis. There were three instances where for a particular subject, run, window length, and speed there was no data. Means were obtained for each subject, run, window length, and speed to be used in the analysis.

Since subject was a random factor, it was important to have a balanced design. However, due to the missing data noted above, the design was not balanced. To remedy this an ANOVA was performed and found no significant difference between the runs ($F(4,44) = 1.57$, $p = .1984$). Run was then dropped as a factor and means were taken over runs two through six for each subject, window length, and speed so that now the design was balanced. This data was then used in an ANOVA, with subject, window length, as speed as the factors (all main effects and first-order interactions were used). F-tests showed a significant difference between the window lengths (F(2,22) = 4.30, p = .0265) and between the speeds (F(2,22) = 71.23, p = .0001). Appendix D is the source table and table 5 is the Bonferroni mean separations, with experimentwise error level of .05, for window length and speed.

Table 5. Bonferroni Mean Separation

	Window length			Speed		
	1/5	3/5	Full	2	4	8
Mean + SD of subjects	1.062 ± .059	1.080 ± .054	1.109 ± .065	1.232 ± .061	1.110 ± .093	0.910 ± .063

Means connected by the same line were not significantly different.

Due to significant interaction between subject and speed (F(22,44) = 4.79, p = .0001) differences between the speeds represents an average over all subjects. The means for each combination of window length and speed were as follows:

Table 6. Window Reduction Relative Error

		Speed		
		2	4	8
Window Length	1/5	1.227	1.082	0.878
	3/5	1.222	1.108	0.911
	full	1.246	1.140	0.941

The difference between the 1/5 and full window lengths, as shown in the mean separation, was greater for speed four (mean difference = .058) and speed six (mean difference =

.063) than for speed two (mean difference = .019). As in the previous studies, the indifference interval falls between the extremes of the actual time range and in this study is approximately six seconds (Figure 11).

Conclusions

The purpose of this experiment was to determine if reduction of the physical length of the visible portion of the LED window could be reduced without sacrificing experimental integrity. Table 5 indicates a significant difference between the full 4.0" window and the 0.8" window. Table 6 further indicates a reduction of relative error for all speeds when window length is reduced from full (4.0") to 3/5 (2.4"). This effect is again seen when window length is reduced from 3/5 to 1/5 (0.8"). This is supported in Figure 10. The slope of the curve clearly indicates a reduction in relative error (averaged over all three actual times) as window size is reduced. For the two faster speeds, the reduction in relative error is a small improvement but since the slower speed is already underestimated, further reduction in relative error is in the direction away from improvement. Reduction in relative error accompanying a reduction in window length was an unexpected result. The implication is that window length can be reduced to 0.8" for the shuttle experiment with little degradation of results for the slower speeds and infact an improvement for the faster speeds.

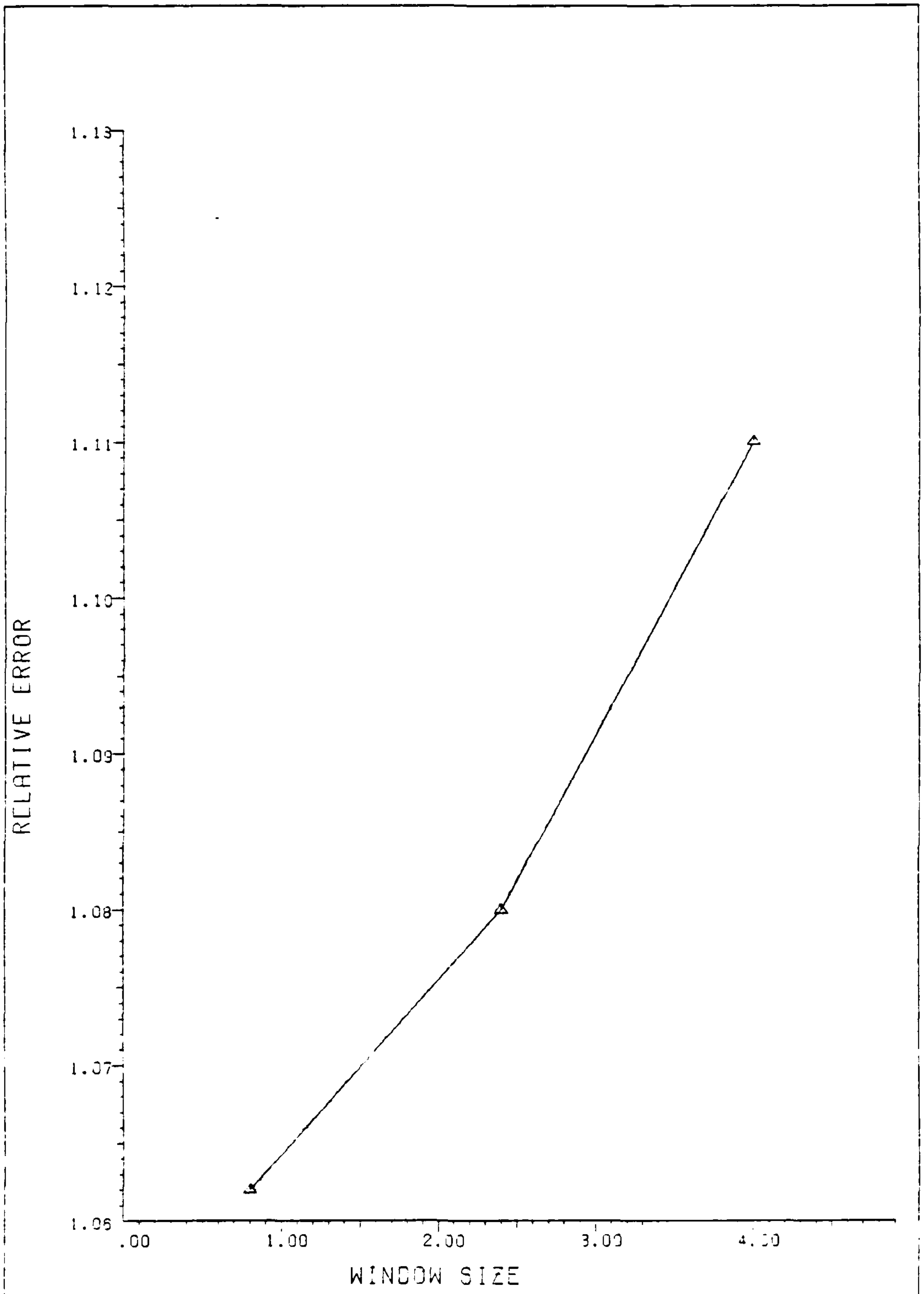

FIGURE 10. RELATIVE ERROR VS. WINDOW SIZE

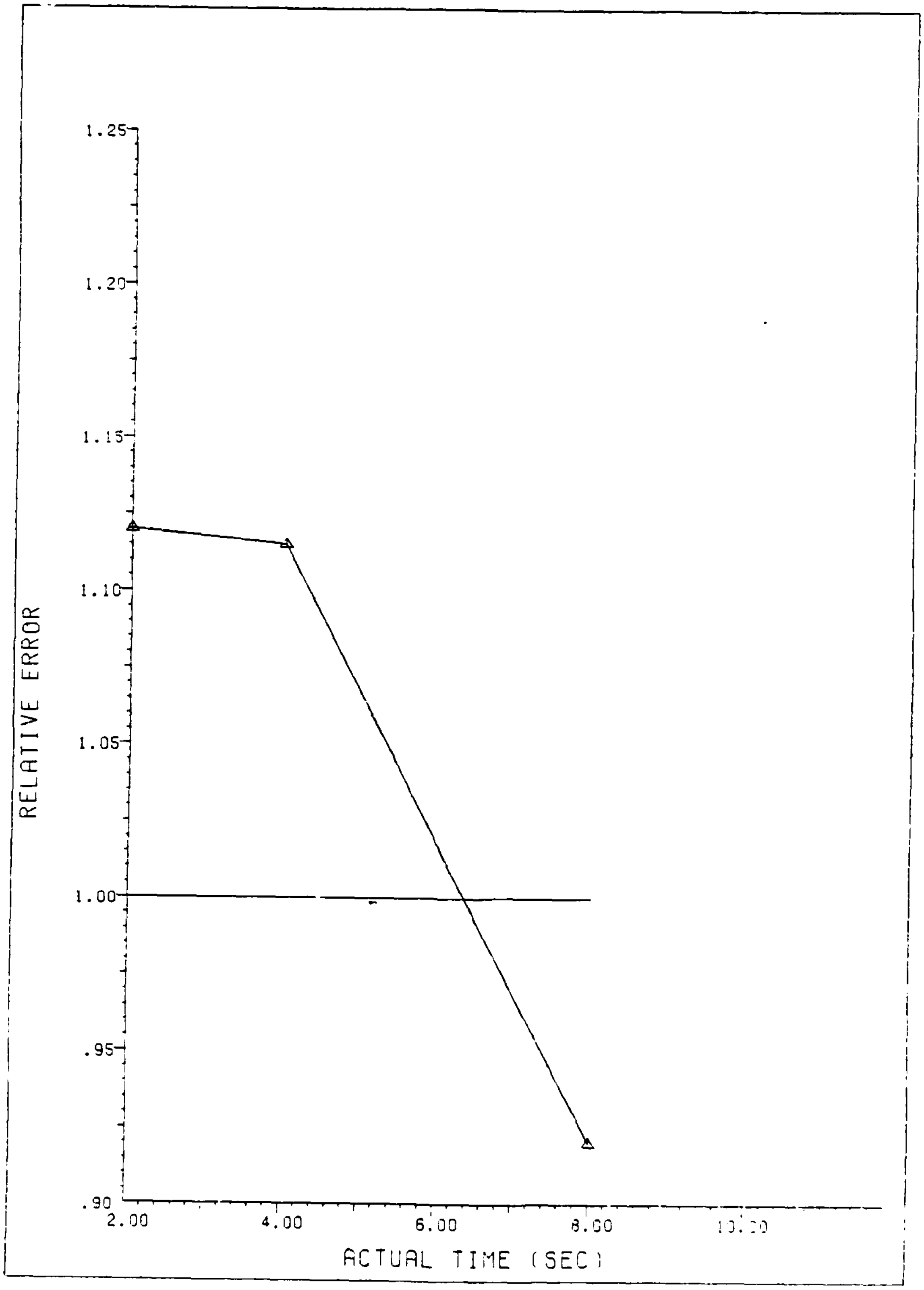

FIGURE 11. RELATIVE ERROR VS. ACTUAL TIME

VI. Research Findings

Findings of the analysis outlined in Chapters III, IV, and V, the conclusions drawn from them, and recommendations for future work will be discussed in this chapter.

Conclusions

The three studies performed in this research have provided enough insight into human time estimation to allow three important conclusions. The trivial conclusion was determined as a result of the pilot study and served only to prove the validity of the modified Jerison device to rigorously test human time estimation. This conclusion was that humans tend to overestimate shorter times and underestimate longer times which agrees with the conclusions of Jerison (1). The feedback study revealed that providing oral feedback was of value to the subject. Providing feedback initially and then not providing feedback showed little sign of degradation of time estimation ability (TEA) after feedback was discontinued. On the other hand, subjects who did not receive feedback initially, and who subsequently did receive feedback on later runs, showed significant improvement in TEA in the form of relative error improvements for shorter times. The conclusions drawn here is that once a subject is exposed to feedback, he will attain a level of proficiency and he will maintain that level even after feedback is removed. This is important in light of the future shuttle experiments because this fortuitously provides the reference needed for each astronaut and then allows for subsequent testing without any chance of re-adjusting that reference. As a direct result of this research, the shuttle experiment has been designed to accommodate this important aspect. Astronauts will be trained in using this device with oral feedback and just prior to launch they will make three initial runs again with visual feedback (digital readout in milliseconds). Once in orbit, each astronaut will make three more runs but will be denied feedback. Upon landing, each astronaut will make one final run without feedback. If the experiment goes as planned, the first three runs will provide the reference, and since this research has shown that any subsequent runs will not significantly change from the first three runs, any change realized in orbit can be directly attributed to factors caused by space flight. The final run should again agree with the first three since the astronauts have indicated from past flights that once they land, all symptoms of temporal distortion go away.

The window reduction study data analysis showed two important pieces of information concerning window dimension. The desire of this study was to prove that equally reliable data could be obtained by reducing the size of the visible window to some dimension which would be shorter than the original. The study was to give some indication as to the minimum size the window could be reduced to without degrading the results. Analysis showed that the relative error was consistently reduced as the window size was reduced over all speeds. This means that the subject will tend to underestimate the actual time when the visible window is shorter. The effects of reducing the window size are particularly dramatic at slower speeds (longer actual times). For the speeds selected in this study, relative error improved for the two and four second speeds. Since the eight second speed was already being underestimated, reducing the window size caused further underestimation, thus the relative error got worse. This would imply that each speed has a related window size which produces a relative error of unity. Slower speeds require larger windows and conversely, faster speeds require smaller windows. The implications of these findings on the shuttle experiment could be significant. If the shuttle experiment is modified to reduce the window to 1/5 of the existing size a 53% time saving can be realized resulting in an increase of data of 213%. Scientists at AFAMRL are presently reviewing the data and are considering software modifications to the shuttle test unit. Final approval on this matter must come from the scientists at NASA.

Recommendations

It is recommended that further studies be conducted in three general areas. First is the area of test unit upgrade or improvements. As these studies progressed, many new ideas came to mind that would reduce the tedium of both the subject and the administrator. Such upgrades would improve the quality of obtained data and would be less likely to alienate subjects. The following is a list of a few possible upgrades:

* Produce a microcomputer interface that would automatically record all data inputs.
* Obtain smaller LED display segments. The existing display segments are .1" long and movement is clearly perceived as discrete increments at the slower speeds.
* Provide an internal battery pack to facilitate portability.
* Incorporate both the TEA test unit and the TEA readout device into one box.
* Install tactile feedback push button switches within a hand held bicycle grip.

The second area where more work could be done is in variation of the test method. One recommendation in this area is a modification of the feedback method. Presently feedback is provided by the administrator in spoken words. This requires the subject to hear correctly, interpret what the numbers mean and then convert them into a relative framework within his head to judge how well he did. A better method would be to visually display each trial result when the subject pushes the respond button. This could be accomplished by constructing LEDs on either side of the target crosshair. These LEDs would remain dark until the respond button was depressed. At that time the appropriate LED would come on corresponding to the location of the masked traveling dot.

Another recommendation in this area is that instead of a visual display, the same experiments could be conducted using headsets and tones. One constant high tone could be inserted into one channel of the headset and a linearly increasing tone could be inserted into the other channel. At some point the monotonicly increasing tone would go off and the subject would estimate when the increasing tone would reach the same pitch as the constant tone by depressing a push button. The results of this could be used to support or dispute the findings of Rousseau et.al (5) that temporal acuity is more reliable and less variable using aural stimulus.

The final and most important area of recommendations is that research needs to be done to find out if this device can be used as a diagnostic tool in the medical and psychological fields. A specific example of such a tool would be a test for attention deficiency disorder (ADD). Presently this anomaly is not detected until after a child begins grade school. By TEA testing at a much earlier age many years of corrective action can be taken before reaching grade school. The hypothesis is that strong correlation will be found between known ADD cases and the coefficient of variation data. This same analysis could be performed for detection of substance abuse since a subjects variance is likely to increase with the use of alcohol or drugs.

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APPENDIX A: Subject Introductory Briefing

TIME ESTIMATION PARTICIPANT

Thank you for participating in this time estimation experiment. The data obtained will be used to help us understand how human beings perceive passage of time. This is of particular importance to The National Aeronautics and Space Administation (NASA). The data obtained from you today will aid in designing equipment and procedures for a similar experiment which will be used on the space shuttle (STS 14) in Oct 84. We ask that you answer all questions truthfully and that you try not to assist yourself during the experiment with timing aids such as tapping or counting. The experiment will last for approximatly 20 minutes and will consist of 25 runs. Each run is initiated by the red button marked "reset". A traveling LED will move from the left side of the raceway toward the right. After the LED has reached the far right side of the raceway you estimate how long it would take it to travel to the marker by pressing the red switch labled "respond" when you think it is there. The traveling LED moves at a constant rate but the rate is randomly selected from five rates when you push the reset button.

APPENDIX B: Pilot & Feedback Study Questionaire

Subject ______________________

Sex _____ ___ Coffee in the past 24 hours

Date _______ ___ Coke in the past 24 hours

Time _______ ___ Normal night of sleep

Use of illegal drugs or alcohol in the past 30 days ___

Use of illegal drugs or alcohol in the past 24 hours ___

Use of over the counter drugs in the past 10 days ___

If yes, what drugs ____________________

Use of prescription drugs in the past 10 days ___

If yes, what drugs ____________________

How many hours since last full meal _______

Run #	Speed	Time	Run #	Speed	Time
1	_____	______	14	_____	______
2	_____	______	15	_____	______
3	_____	______	16	_____	______
4	_____	______	17	_____	______
5	_____	______	18	_____	______
6	_____	______	19	_____	______
7	_____	______	20	_____	______
8	_____	______	21	_____	______
9	_____	______	22	_____	______
10	_____	______	23	_____	______
11	_____	______	24	_____	______
12	_____	______	25	_____	______
13	_____	______	26	_____	______

APPENDIX C: Window Reduction Study Subject Data Record

This appendix contains the form used to record subject identification and run data for the window reduction study. Such information as whether drugs or alcohal had been used by the subject recently was to be entered as comments. The series of questions asked in the previous studies (Appendix B) had to be eliminated in order to accommodate all data entries on one page.

Time Estimation Ability Data

Subject ______________________ Date __________ Time ______

Sex ____ Comments ______________________________

Run #	Speed	Time
-------Window Size -----		
1	______	________
2	______	________
3	______	________
4	______	________
5	______	________
6	______	________
7	______	________
8	______	________
9	______	________
10	______	________
11	______	________
12	______	________
13	______	________
14	______	________
15	______	________
-------Windoow Size ----		
16	______	________
17	______	________
18	______	________
19	______	________
20	______	________
21	______	________
22	______	________

Run #	Speed	Time
23	______	________
24	______	________
25	______	________
26	______	________
27	______	________
28	______	________
29	______	________
30	______	________
-------Window Size -----		
31	______	________
32	______	________
33	______	________
34	______	________
35	______	________
36	______	________
37	______	________
38	______	________
39	______	________
40	______	________
41	______	________
42	______	________
43	______	________
44	______	________
45	______	________

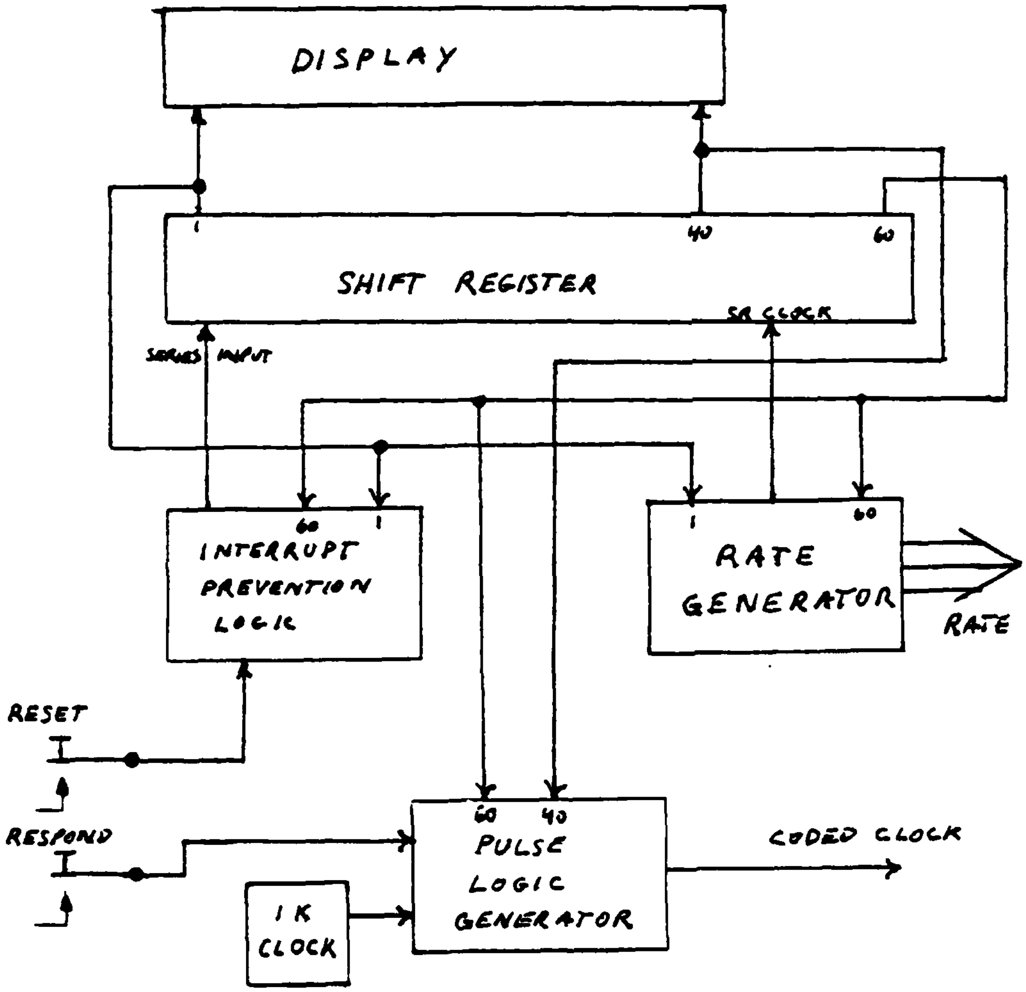
APPENDIX D: Circuit Description

The prototype TEA test set was constructed in two units; the TEA test unit and the TEA readout device. The following is a functional description of the circuitry of each unit.

Tea Test Unit

Originaly, the test unit was to be the tester which would ultimatly be used on STS missions. As such, emphasis was placed on simplicity and low power budget. The logical choice for logic devices was CMOS technology and was used throughout. The test unit can be broken into four major sections as seen in the block diagram on page 59. A shift register consisting of eight 8-bit shift registers is used to drive the 40 LED display and to generate bit number 60. Though the eight shift register chips provide 64 individual shift registers, only 60 are required for this device.

Operation is initiated when the reset button is pressed. The interrupt prevention logic immediately provides a logic one to the serial input of the first shift register. After the first shift register (SR) clock, bit one of the SR is fed back to the interrupt prevention logic to disable the SR input. The SR input remains disabled until SR bit 60 enables it again. The disable function created by SR bit one immediately creates a logic zero at the SR input and it gates out inputs from the reset button.


DISPLAY
1
40
60
SHIFT REGISTER
SR CLOCK
SERIES INPUT
60
1
INTERRUPT
PREVENTION
LOGIC
1
60
RATE
GENERATOR
RATE
RESET
RESPOND
60
40
PULSE
LOGIC
GENERATOR
CODED CLOCK
1K
CLOCK

The output of a multiplexer, which has five clock rates as its inputs, provides the SR clock from within the rate generator circuit. The multiplexer is addressed by a binary counter which is configured to count zero through decimal four (this was re-configured for the window reduction study to provide only three LED rates). The counter is clocked, and thus counting, until SR bit one has been activated as previously explained. This disables the clock input to the counter. The address that the counter stops at determines the output (SR clock rate) of the multiplexer and is provided as an output to the readout device. Randomization of the LED rates is assured since the subject is unable to predict what the counter output address is when he presses the reset button. The counter remains disabled until SR bit 60 enables it again, thus maintaining a constant rate throughout the experimental trial.

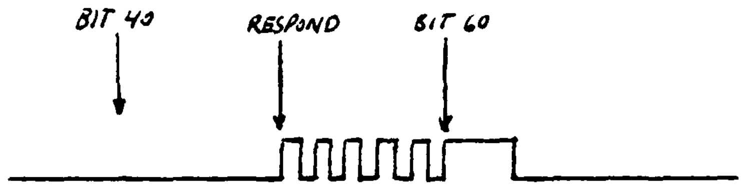
The pulse logic generator is continuously provided a one thousand bit/second clock. When the respond button is pushed, the clock is gated out to the readout device in the following manner:

<u>CONDITION ONE</u>

Prior to SR bit 40 ======> No output.

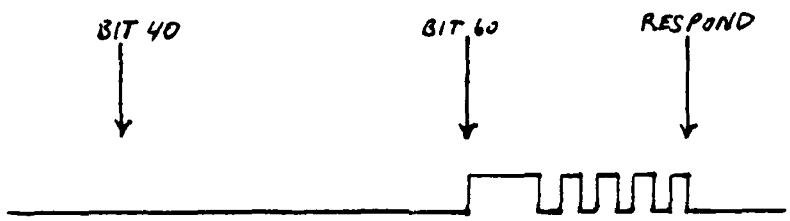
CONDITION TWO

After SR bit 40 but before SR bit 60 ======> Clock output until SR bit 60 - then one long pulse.



CONDITION THREE

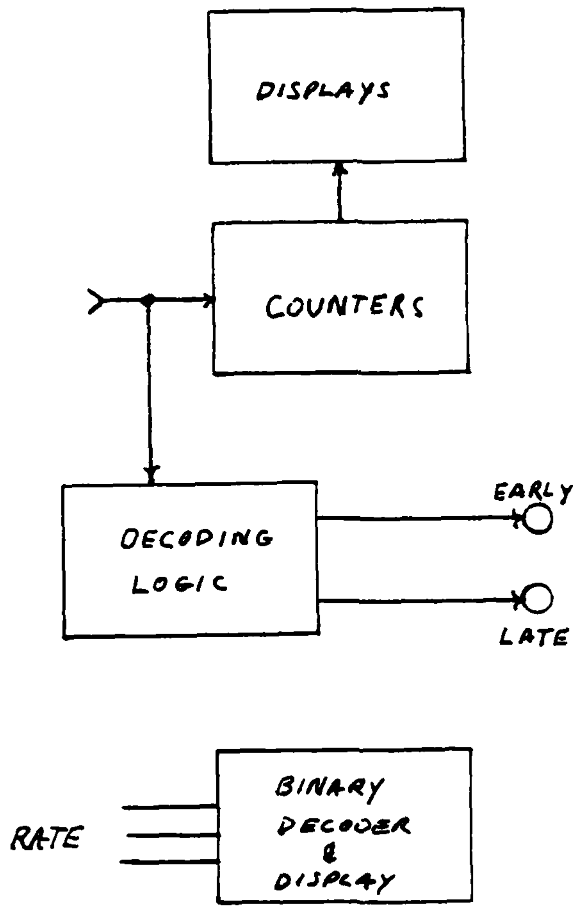
After SR bit 60 ======> One long pulse at SR bit 60 - then continuous clock output until respond is pressed.



Readout Device

The block diagram on page 62 will be used to describe the functional description of the readout device. The counter input is provided to the binary to decimal decoder which in turn drives a single seven segment LED display. This circuit is autonomous to the other circuits in this unit and serves the sole function of presenting a single digit display of the Led speed.

The coded clock input is goes to both the display counters and the decoding logic. Four decade counters are cascaded together to provide a digital readout of seconds


DISPLAYS
COUNTERS
DECODING LOGIC
EARLY
LATE
RATE
BINARY DECODER & DISPLAY

and milliseconds. The decade counters provide input to four seven segment Led display drivers which in turn provide the input to the seven segment displays. The carry bit of the "seconds" indicator is used to drive an overflow LED. This Gives the operator an indication of counts which are in excess of 9.999 seconds.

Within the decoding logic, the coded clock input is provided to two parallel paths which are identical with exception to the time constants established within each path. The condition of a long pulse (4 milliseconds) first in the train of one millisecond pulses will cause a logical one output which turns on the the late LED indicator. The condition of a long pulse following the train of short pulses causes a logical zero output which turns on the early LED indicator.

APPENDIX E: Window Reduction Source Table

Source	DF	Sum of Squares	Error Term	F value	P value
subject	11	.247	error	8.06	.0001
window	2	.040	subject*	4.30	.0265
speed	2	1.904	subject* speed	71.23	.0001
subject* window	22	.103	error	1.67	.0723
subject* speed	22	.294	error	4.79	.0001
window* speed	4	.008	error	0.73	.5753
error	44	.123			
total	107	2.719			

VITA

Captain Daniel C. Kinney was born on 17 November 1951 in Waterville, Maine. He graduated from from high school in South Portland, Maine, in 1970 and enlisted in the USAF as an avionics technician. In 1977 he was accepted into the bootstrap progran at Park College, Parkville, Missouri and received the degree of Bachelor of Arts in Engineering Electronics in may 1978. He immediatly went to Officer Training School and was commissioned in September of that year. From there he went to the Communication Electronics Officer School, Keesler AFB, Mississippi. In April 1979 he was assigned to the Technical Services Directorate, Headquarters Air Force Office of Special Investigations (HQ AFOSI), Washington, DC., as the Research and Development Officer, until entering the School of Engineering, Air Force Institute of Technology, in June 1983.

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Block 19: Abstract: Early in the Space Shuttle program, a temporal distortion problem, was noticed. The Air Force Aerospace Medical Research Laboratory (AFAMRL) was made responsible for research of the anomaly.

A test unit was fabricated using a modified Jerison display which consisted of a traveling LED. At the end of the LED travel, the light went behind a masked area. Subjects estimated when the light reached the crosshair on the mask.

After prototype fabrication, a test procedure was established consisting of three experiments. The purpose was to validate the test unit and to investigate modifications which would optimize efficiency. Seven subjects participated in a pilot study where each performed three runs of 26 trials per run. Results compared to those found in previous work. This, coupled with an overall coefficient of variance of 15%, was an indication of a rigorous experiment.

To analyze the effects of oral feedback, 18 subjects were tested in two groups. Each subject performed five of 26 trials. Group A did not receive feedback for the first three runs and did receive feedback for the last two runs. The opposite feedback sequence was provided to group B. Analysis revealed that a significant drop in relative error ($p \leq .05$) was experienced by group A subjects, once feedback was provided. For group B subjects the changes were insignificant ($p \leq .05$) when feedback was removed. Thus a reference baseline is formed for the later case where the subject relative error does not change after feedback is removed. Astronuots will receive feedback prior to flight and will not receive it during flight.

Reducing the time required to perform each trial was the goal of the third experiment in which three window sizes were selected. Twelve subjects performed six runs of 45 trials each divided into three groups of 15. Each group was performed with one of the three window sizes. Analysis showed a decrease in relative error with a reduction in window size. This reduction in relative error represents a minor improvement for most times while increasing efficiency by 203%.

END

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