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USAARL REPORT NO. 74-9

STATIC EVALUATION OF ABSOLUTE ALTIMETER DISPLAY DESIGNS

STUDY I

By

Thomas L. Frezell
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February 1974

U. S. ARMY AEROMEDICAL RESEARCH LABORATORY

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ABSTRACT

Six absolute altimeter display designs were evaluated in the static mode. Performance was measured with respect to subjects' reading accuracy, speed and preference. The subjects consisted of experienced Army aviators and non-flying college students. The results showed a significant difference between display types as well as between aviators and students.

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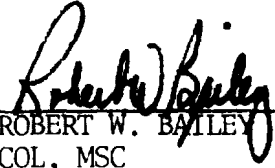

ROBERT W. BAILEY
COL, MSC
Commanding

TABLE OF CONTENTS

	<u>Page</u>
List of Tables	v
List of Figures	vi
Abstract	iii
Introduction	1
Method	2
Results and Discussion	8
Literature Cited	15

LIST OF TABLES

<u>Table</u>	<u>Page</u>
1. Subject Data	5
2. Summary of Analysis of Variance	9
3. Summary of Ranked Preference Questionnaire	14

LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
1. Pointer "0" Top	5
2. Pointer "0" Bottom	5
3. Digital Pointer "0" Position with Horizontal Digits	6
4. Digital Pointer "0" Top Vertical Digits	6
5. Bezel Tape "0" Top Vertical Digits	7
6. Bezel Tape "0" Bottom Horizontal Digits	7
7. Mean Response Time in Seconds for Altimeter Display Type. .	9
8. Frequency of Error to Displays.	11
9. Frequency of Error \geq 100 Feet But $<$ 1000 Feet	12
10. Frequency of Error \geq 1000 Feet	13

INTRODUCTION

The necessity of the altimeter for the conduct of safe flight has been recognized for over 190 years.⁵ The significance of this instrument, however, has gained more prominence with the increasing requirement for more exact altitude control, which exists for the advanced flying machines of today and the scenarios they fly, both commercially and tactically.

The controversy over which altimeter design is best has raged very nearly from the advent of the instrument itself without resolution. The status of the controversy, perhaps, is best reflected by Schum, Robertson and Matheny's statement, "No single display type emerges as a final answer to the display problem."⁵ This they consider is partly due to the increasing requirements placed on the altimeter display while not addressing the basic problems which exist in these displays. This is perhaps most apparent when one considers that the old three-pointer altimeter continues to be installed in aircraft being produced today when it has been shown consistently to be one of the worse possible designs.^{2,4,6}

Because of the increased requirement for precise altitude control mentioned earlier, absolute altimeters are becoming more prevalent. Therefore, it would appear that a point in time may be at hand when a man-compatible design could be interjected into altimeter displays, which will meet with a minimum of resistance. Minimal resistance should result because the radar altimeter will be a new instrument for most and thus, it will be unnecessary to overcome a learned and accepted design. This, however, carries with it the responsibility that maximum effort be put into the design of these displays to insure they transmit information in an accurate and timely manner. To date, when one views many of the absolute altimeter designs being proposed, one realizes that in many cases they do not include much of the knowledge gained in barometric altimeter investigations contributed over the years, but appear to be perpetuating many known design deficiencies. In addition to not adhering to good design practices, few, if any studies could be found by these authors which have been conducted to decide what might represent an optimal design for absolute altimeters. Consequently, this study represents one effort of many which should be conducted to make this determination.

This investigation utilized three basic altimeter designs. They were as follows: The direct pointer, pointer with digital display, and the outer bezel tape with digital display. Variations of these basic types include displays with zero bottom or zero top and digits placed horizontally or vertically. These instruments were investigated in the static mode within the laboratory. Though any design must ultimately be evaluated in the dynamic mode, static studies have been shown to provide a reliable and time effective method for basic evaluation and are often capable of making the same discriminations as dynamic tests.^{2,6,7} Also, the static test is quite useful in identifying design faults which may be unexpected, even in a critical examination of an instrument. This diagnostic quality of static testing early in the design and development process can help correct many deficiencies before development has been carried too far for corrections to take place because of time and expense considerations.

The displays used in this investigation were designed with dimension and facial characteristics which were in consonance with appropriate MIL Standards and specifications for round face displays. Measurements of performance included time and accuracy of response in addition to preference information.

METHOD

Subjects

Subjects for this study were ten (10) Army aviators and ten (10) non-flying college students. Earlier studies maintain a high correlation of reliability between pilots and non-pilots in static experiments.¹ Demographic data are presented in Table 1.

TABLE I
SUBJECT DATA

ARMY AVIATORS	
N = 10	
Mean Age Years	30.7
Mean Total Flight Time Hours	2775.0

COLLEGE STUDENTS	
N = 10	
Mean Age Years	18.3

Apparatus

Testing was conducted in a six by eight foot experimental room with a video monitor. In a separate room slides were projected and relayed to the monitor via a closed circuit video system. The size of the displays were controlled to match that of the current altimeter displays being used within the Army inventory. The image projection time was controlled by means of an electronic iris connected through a timing circuit and voice keyed relay. The projected image remained until the subject's initial verbal response triggered the iris to the closed position. There was a standard time of five (5) seconds between each display presentation during which the subject's response time and reading was recorded.

The specific displays utilized are illustrated in Figures 1-6. Figure 1 is the direct pointer altimeter with the zero located at the top. Figure 2 is the direct pointer with zero at the bottom. The digital pointer with zero at the bottom and horizontal digits can be

seen in Figure 3. Figure 4 is a digital pointer with zero at the top and vertical digits. A tape bezel display can be seen in Figure 5 with vertical digits and zero at the top. Its counterpart as seen in Figure 6 contains zero at the bottom and a horizontal digital display.



Figure 1
Pointer "0" Top

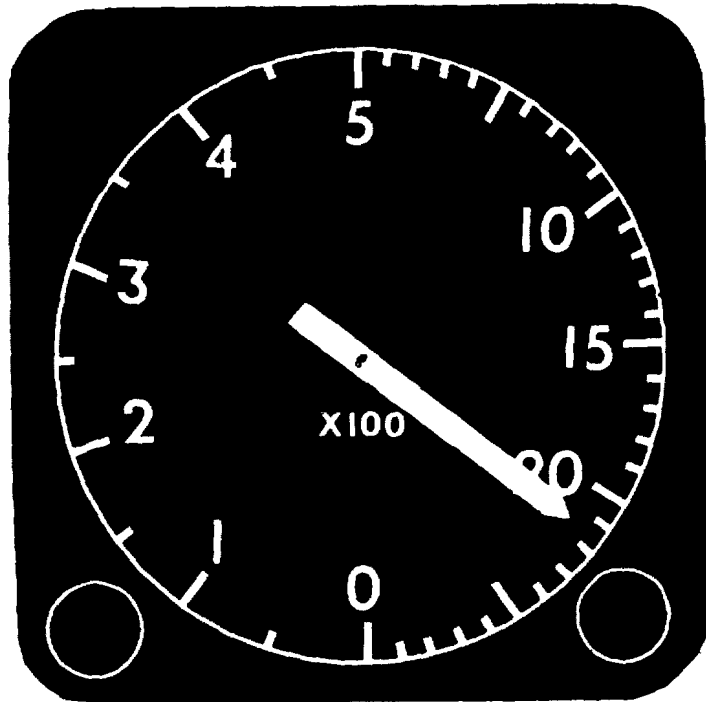


Figure 2
Pointer "0" Bottom

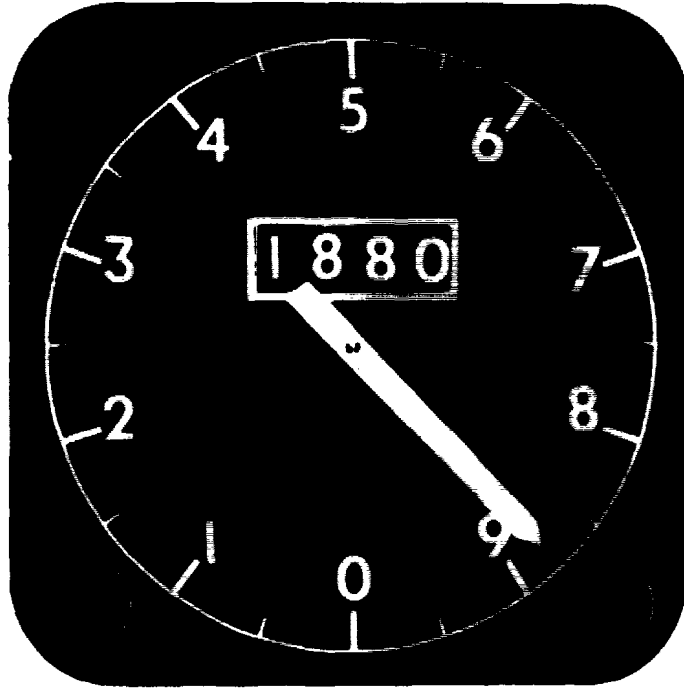


Figure 3

Digital Pointer "0" Bottom With Horizontal Digits

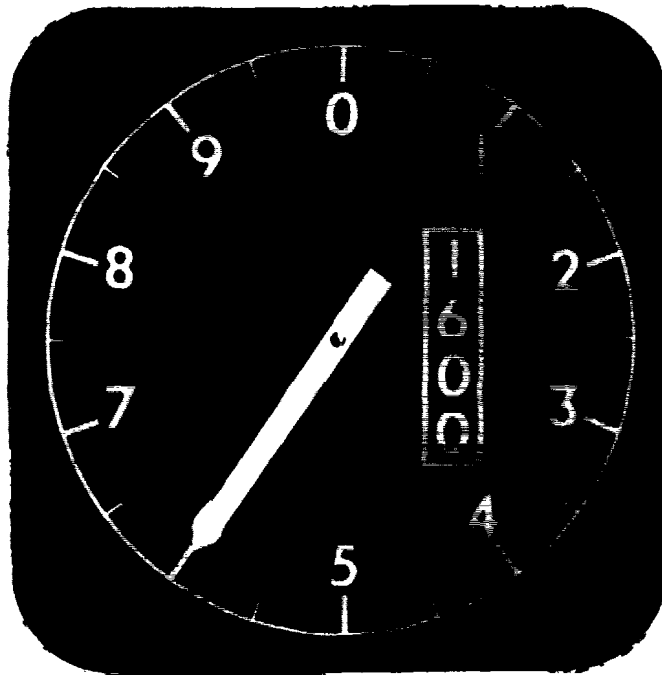


Figure 4

Digital Pointer "0" Top Vertical Digits



Figure 5

Bezel Tape "0" Top Vertical Digits



Figure 6

Bezel Tape "0" Bottom Horizontal Digits

Procedure

Subjects were seated in the test room at a viewing distance of 22 inches. A standard set of instructions was read to each subject which in essence asked the subject to respond as quickly and accurately as possible. It was also indicated at this time that all values to be presented would have zero units. After the instructions were completed a pre-test was administered. This pre-test consisted of presenting several trials for each of the displays to insure that subjects had familiarity with each display and had no difficulty in interpretation. Any questions asked by the subjects were answered at this time. At the conclusion of the pre-test the experimental session was begun. The session lasted 40 minutes and included 20 presentations of each altimeter display. Thus, each of the 10 subjects was required to make a total of 120 readings. There was a one minute rest period between a new set of 20 displays. The presentation order of the six altimeters was randomized across subjects. Values presented ranged from 0-2500 feet. Values ranging from 0-250 were selected from a table of random digits and multiplied by ten.

RESULTS AND DISCUSSION

The results will be presented and discussed in terms of display types 1-6 which correspond to Figures 1-6 as presented in the apparatus section.

The response time data were subjected to a two-factor analysis of variance with repeated measures on one factor. The significance level selected was .01. The results of this analysis are summarized in Table 2.

TABLE 2
Summary of Analysis of Variance
For Response Times

Source	SS	df	MS	F
Between Ss	49.51	19	2.61	
A (Groups)	13.621	1	13.621	6.830
Ss Within Groups	35.893	18	1.994	
Within Ss	211.32	100	2.11	
B (Display Type)	149.101	5	29.820	63.181*
AB	19.737	5	3.947	8.363*
B x (Ss within Groups)	42.478	90	.471	

*p < .01

It can be seen from this table that the factor of display type was significant as was the group by display type interaction. A histogram of the cell means of this interaction can be seen in Figure 7.

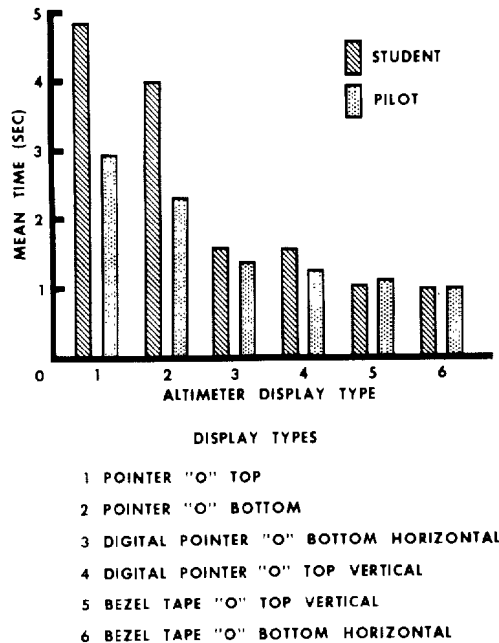


Figure 7

Mean Response Time in Seconds For Altimeter Display Types

It is apparent that for most display types aviators were faster responders than were the non-aviators. However, with digital displays, differences in time to respond for the most part were very slight. The pointer design produced the largest mean response times for both groups. This altimeter, of course, required more interpolation since no digital indicator was provided. The interpolation fraction between graduation marks to achieve accuracy to the nearest 10 feet, the resolution used in this investigation, was one fifth. Response times might be expected to decrease if the interpolation fraction was made larger and that the inclusion of more graduation marks did not add clutter to the extent that they degraded readability. Additionally, there was a scale change on this altimeter which could lead to increased reading times. It can also be noted that the disparity between mean response times for aviators versus non-aviators was greatest for this pointer display, probably due to aviator practice in interpolation and reading pointer type altimeters. With regard to the altimeters with digital read-outs, those with the pointers yielded higher response times than did the bezel tape type displays. This, in large measure, was a function of digits being blocked by the pointer. This situation could, in part, be remedied by a thinner stem design. However, this would not be in keeping with present specifications and standards for the design of pointers. When blockage occurred there was also a requirement for subjects to go to the pointer to determine altitude which increased time. The bezel type displays, on the other hand, did not present this blockage problem. Consequently, times for both aviators and non-aviators were lowest for this type of display relative to the others.

Frequency of errors across display types can be seen in Figure 8.

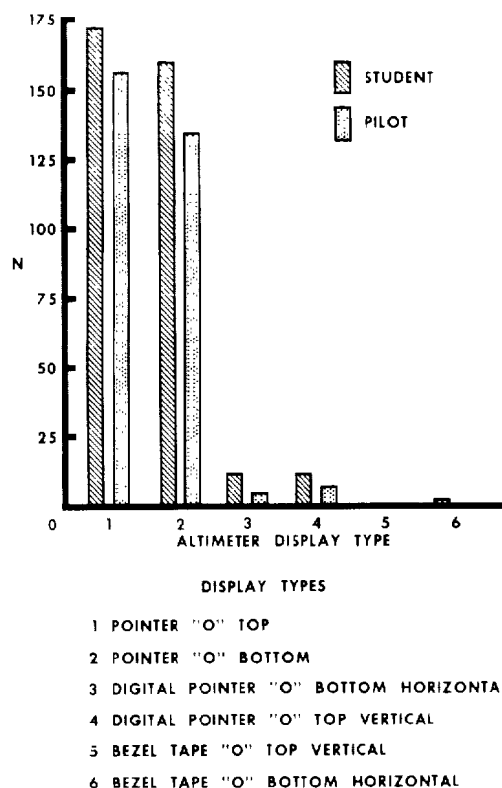
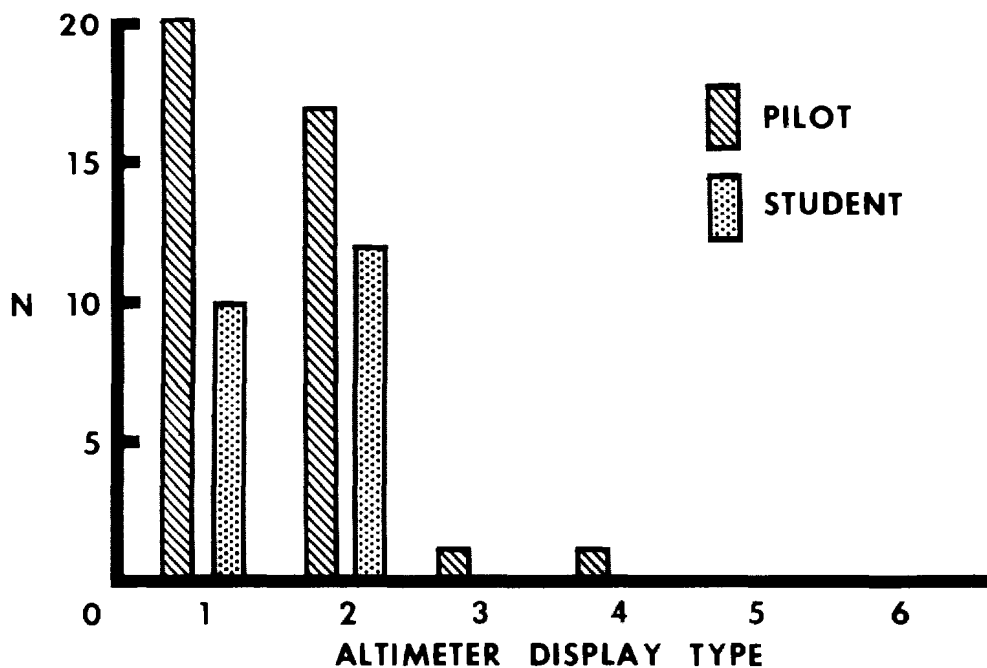


Figure 8

Frequency of Error to Displays

This frequency of error measure revealed, as did response time, that aviators performed better than their counterpart non-aviators with the exception of design 5 in which they were equal. Figure 8 illustrates that most errors were associated with the pointer type displays. The high error rate for the straight pointer display can again be attributed to the interpolation task discussed earlier. The digital pointer displays which were next with respect to error is an outcome which could again be attributed to the blockage problem. The display types with the lowest frequency of errors were the bezel type digital displays. Magnitude of errors for display types can be seen in Figures 9 and 10. Figure 9 represents the number of errors which were equal to or greater than 100 feet but less than 1,000 feet.



DISPLAY TYPES

- 1 POINTER "O" TOP
- 2 POINTER "O" BOTTOM
- 3 DIGITAL POINTER "O" BOTTOM HORIZONTAL
- 4 DIGITAL POINTER "O" TOP VERTICAL
- 5 BEZEL TAPE "O" TOP VERTICAL
- 6 BEZEL TAPE "O" BOTTOM HORIZONTAL

Figure 9

Frequency of Error \geq 100 Feet But $<$ 1,000 Feet

It is evident that the non-digital pointer displays were most often associated with these type errors. These errors, in most cases, were such that subjects gave readings that were lower than the actual readings of the altimeters. The frequency of errors in excess of 1,000 feet was also broken down across display types. These errors, though few, can be seen in Figure 10.

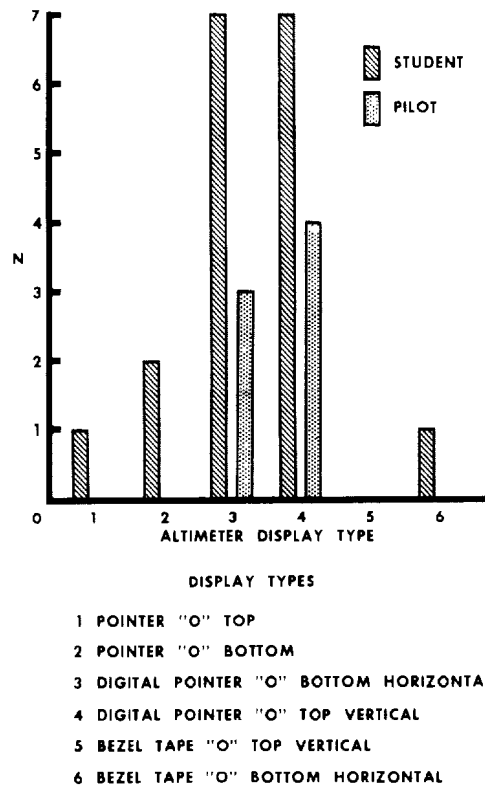


Figure 10

Frequency of Error \geq 1,000 Feet

Errors of this magnitude were most often associated with the digital pointer displays. Upon examination of the data, it was concluded that blockage of the drum by the pointer contributed most heavily to this type error. It can be seen, however, that aviators were not as frequently affected by this problem as were non-aviators.

Due to certain logistical limitations, the design was not a balanced design and, as such, does not permit, one, on the basis of the error data, to determine the relative impact of zero at the bottom versus zero at the top, nor the impact of vertical versus horizontal digits. The exception is the pointer display with regard to zero location. With this display, zero at the bottom was associated with shorter response times and fewer errors of all types. This performance for non-aviators coincides with the preference data given in Table 3, which represents the frequency with which displays were ranked for preference.

TABLE 5

Summary of Ranked Preference Questionnaires

RANKED PREFERENCE		DISPLAY TYPE											
		POINTER				DIGITAL POINTER				BEZEL			
		"O" TOP		"O" BOTTOM		"O" BOTTOM		"O" TOP		"O" TOP VERT.		"O" BOTTOM HORIZ.	
		AVIATOR	STUDENT	AVIATOR	STUDENT	AVIATOR	STUDENT	AVIATOR	STUDENT	AVIATOR	STUDENT	AVIATOR	STUDENT
MOST	1	0	0	0	0	1	0	0	1	4	4	4	5
↑ ↓	2	0	0	0	1	0	0	2	3	4	4	4	2
	3	1	1	0	0	5	2	3	3	1	1	0	2
	4	0	0	1	2	2	4	4	3	1	1	2	0
	5	6	5	3	2	0	3	1	0	0	0	0	0
LEAST	6	3	4	6	5	1	1	0	0	0	0	0	0

This does not hold true of the aviators however, for more preferred zero at the top. This result would be in keeping with their familiarity with current altimeter displays. The preference data also indicates that the bezel type digital display, which was associated with the best performance, was well liked by both the aviators and non-aviators. Of the bezel designs aviators were evenly split with regard to zero bottom, zero top and horizontal versus vertical digits. More non-aviators, however, preferred the zero at the bottom and horizontal digits. It is also interesting to note that one aviator ranked the digital pointer display with zero bottom and horizontal digits as most preferred.

A more optimal design than those used in this investigation, given a 0-3000 feet range were acceptable, might consist of a bezel digital display with the outside display having two scales; one going from 0-1000 feet, the other going from 1000-3000 feet. The first scale might occupy 50% of the face, the latter 50% of the face.

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