AD NUMBER: ADA800380
LIMITATION CHANGES
TO: Approved for public release; distribution is unlimited.
FROM: Distribution authorized to DoD only; Administrative/Operational Use; 1 Aug 1950. Other requests shall be referred to Air Materiel Command, Wright-Patterson AFB, OH 45433.
AUTHORITY
AMRL ltr dtd 27 Aug 1974

L-C 4092

I 85523

AF TECHNICAL REPORT No. 6024 August 1950

SOME VARIABLES AFFECTING INSTRUMENT CHECK READING

Shirley C. Connell

United States Air Force
Air Materiel Command
Wright-Patterson Air Force Base, Dayton, Ohio

AF TECHNICAL REPORT NO. 6024 August 1950

SOME VARIABLES AFFECTING INSTRUMENT CHECK READING

Shirley C. Connell

Aero Medical Laboratory
E. O. No. 694-27

United States Air Force
Air Materiel Command
Wright-Patterson Air Force Base, Dayton, Ohio

Air Force-WPAFB-(A)-O-1 SEP 50 600

ABSTRACT

As part of extended studies of human factors in aircraft instrument check reading, two studies were conducted in one of which subjects check read panels of simulated instruments, and in the other singly presented numbers ranging in size from two to seven digits. In the first study, panels of four identical simulated indicators, all aligned at the same setting, were checked for significant deviations from the reference setting. This simulated part of the task of pilot or flight engineer in checking the engine instrument panel of a four-engine airplane. Three panels were compared, each embodying a different common principle of indication. Average time and percent of errors of twenty subjects in detecting significant deviations in setting among four circular dials with rotating pointers were approximately half as great as time and errors in detecting deviations among four direct reading counters or indicators with a scale rotating behind a fixed pointer.

In another separate study, numbers varying only in number of digits (from two to seven digits) appeared in the same exposure apparatus as was used above. Time and errors in detecting differences between verbally and visually presented numbers were recorded for twenty subjects. Speed and accuracy increased directly as the number of digits decreased from seven to two digits, indicating that in counter type indication, there is almost a linear increase in time and a similar increase in errors for each addition of a column beyond two columns.

PUBLICATION APPROVAL

For the Commanding General:

WALTER A. CARLSON
Colonel, USAF (MC)
Chief, Aero Medical Laboratory
Engineering Division

I. INTRODUCTION

Increasing knowledge of the nature of pilot activities in flight and evidence of the prominence of instrument check reading among these activities (5) (6) has occasioned a number of recent studies relating to human factors in aircraft instrument check reading. This research represents part of an effort to determine the best design and arrangement of instruments for check reading purposes. It relates specifically to the question: In what form may information be presented most advantageously when it is necessary only to detect a deviation from the desired reading on any one instrument in a series of like instruments? Also, with regard to the utility of direct reading counters: What is the relation between number of digits and the speed and accuracy of checking such a counter?

Preceding reports have presented data concerning the effects of instrument design and instrument grouping on the comparative speed and accuracy of check reading. Warrick and Grether (8) demonstrated the advantage of pointer alignment for check reading instrument groups and the desirability of having the pointers aligned at the 9 o'clock dial position. White, (9) studying both performance and eye movements during the check reading of instrument groups, found that a moderate dial size (1.75 inch diameter) was slightly superior to dials larger or smaller in size. Grether and Connell (4) studied the check reading merits of single indicators utilizing rotating pointers, rotating scales, linear scales with moving pointers, linear moving scales with fixed pointers, and direct reading counters. Changes in setting were generally detected more quickly and accurately on an indicator with a rotating pointer or with a direct reading counter than with the other modes of indication. Experiment I of the present study evaluated three of these same modes of indication with reference to the check reading of instrument groups. Rotating pointers, rotating scales, and direct reading counters were compared on the basis of check reading responses to the multiple presentation of four identical, horizontally aligned instruments. This latter arrangement is a suitable grouping for engine instruments in four-engined aircraft.

Because of the obvious advantages of counters for direct presentation of numerical data and the excellent results they have given when compared with other instruments (2), it is desirable to know some of the factors contributing to differences among counters themselves. In Experiment II the factor of number of digits presented on a counter was evaluated in relation to speed and accuracy of check reading, with numbers varying in length from two to seven digits. Such information is of value in delimiting the effectiveness of counter type indicators and for understanding the perception of numbers.

Figure 1

EXPOSURE APPARATUS WITH SCREEN RAISED. SUBJECT (LEFT) READY TO RESPOND TO STIMULUS PANEL.

II. EXPERIMENT NO. I

Check Reading Comparison of Instrument Groups Consisting of Rotating Pointers, Rotating Scales, or Direct Reading Counters

Purpose:

The purpose of this study was to determine the influence of mode of indication on the speed and accuracy of check reading a group of instruments. Three modes of indication were compared; rotating pointers on fixed dials, rotating dials with fixed pointers, and direct reading counters.

Apparatus, Procedure and Subjects:

Three separate mock-up panels were prepared, each comprising a 7- by 13-inch dull black surface on which were mounted four identical, horizontally aligned simulated instruments, adjustable from the rear. A photograph of one of these panels and the accompanying testing apparatus is shown in Figure I. The same quantitative information, i.e., information of the kind presented by a standard airspeed indicator, was afforded by all of the instruments but the mode of indication differed from panel to panel. Panel 1 contained four circular dials with rotating pointers similar to Indicator A of Figure 2. Panel 2 presented the same information on instruments with rotating dials and fixed pointers. On this panel, only a 120 degree arc of the rotating dial was visible behind the window framing the pointer (See B of Figure 2). For uniformity, readings on both panels were confined to the left-hand dial quadrant, the area previously found best for rapid check reading (8). Panel 3 accommodated four three-digit direct reading counters (C of Figure 2).

Other than the critical differences in form or shape, all elements of the instrument designs were held as constant as possible to minimize the number of dependent variables. Scales, numerals and pointers were identical in form and dimension for all instruments, complying with standards suggested by the Army-Navy NRC Vision Committee for research on visual displays (1). A 50- to 500-mile airspeed scale was used on the dial type instruments with minor graduations every 10 miles, intermediate graduations every 50 miles, and major graduations every 100 miles. Dial faces and counter numerals were reverse (white on black), glossy finish photographs of drawings.

The three simulated instrument panels were installed directly behind the window in the 18- by 24- inch black bakelite panel in such a way that they could be interchanged and shown separately in ... irregular sequence. The bakelite shade which covered the stimulus material between trials was manually operated by a string and pulley arrangement at the rear of the panel. Raising the shade activated a clock which was stopped by the subject when the correct response was made. Upon completion of the response, the shade was again lowered, permitting the experimenter to adjust the instrument for the next trial. An illumination of approximately 30 foot lamberts, as measured by the Macbeth Illuminometer, was maintained at the white markings on the instrument faces.

As may be seen in Figure 1, the subject held in his lap a two-way toggle switch for registering his response. He was instructed to push the switch handle in one direction if the four instruments shown were aligned at the same setting and in the other direction if any one of the four deviated in setting from the other three. To avoid the possibility of introducing any bias, some subjects were instructed to respond by moving the switch to the left to indicate a "same" response and some were instructed to respond by moving the switch to the right. The clock for timing continued running until the correct switch movement was made. In case of error, the subject always corrected his response before the shade was lowered in preparation for the next trial. The exact measure of response time thus constituted the interval between the shade's clearing the top of the exposure window and the correct switch movement. Knowledge of subjects' switch movements was conveyed to the experimenter through a group of signal lights at the rear of the panel.

Following verbal instructions and a brief practice session, the subject was seated before the test panel, eyes level with and 28 inches from the display. After a ready signal from the experimenter, the shade was raised and the subject observed the alignment or misalignment of the four instruments on the exposed panel and indicated his response by manipulation of the switch. When the correct response had been made, the shade was lowered, time and errors were recorded, and a new alignment condition set in the panel in readiness for the next trial. When all of the 15 trials for any one panel were completed, it was removed and another panel inserted behind the stimulus window.

Twenty male students from Miami University, Oxford, Ohio, served as subjects. One subject had had about one year of air force pilot training, another claimed some civilian flying experience.

Each of the twenty subjects received the stimulus panels in a different order, so that each panel appeared an equal number of times at each position in the series of three. The fifteen trials per subject for any one panel included five trials with all four instruments aligned at 180 miles per hour, five trials with one of the four deviating 20 miles either way from the 180 miles per hour setting, and five trials with one of the four deviating 40 miles either way from the 180 miles per hour setting. Extensive counterbalancing insured equal distribution of deviations of each direction and magnitude among each of the four instruments of any one panel. When deviations occurred they were at precise amounts of 20 or 40 miles from the reference setting but the reference setting itself (180 miles per hour) was not always strictly maintained. One fifth of the reference settings (of which there were three or four per panel) varied from three to seven miles from 180 miles per hour. This ranged within one graduation mark of the reference setting on the scale type indicators. An approximation of true instrument reading conditions was provided by this tolerance as instruments infrequently maintain a static setting. Subjects were to disregard these misalignments and note only deviations of 20 miles (or two graduation marks) or more from the 180 mile per hour setting.

With 20 subjects used in each comparison, 300 judgements on each panel were obtained.

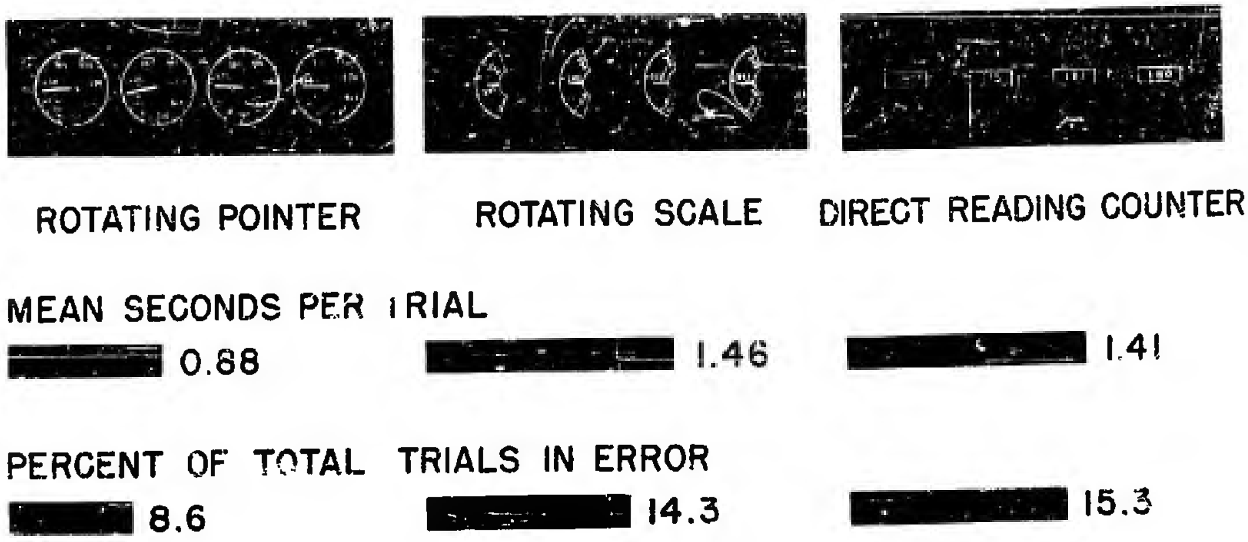

Figure 2.

RESULTS OF EXPERIMENT NO. 1
TIME AND ERRORS IN CHECK READING THREE PANELS OF SIMULATED INDICATORS

TABLE I

"t" Values for Differences in Time to Check Read Three Panels of Simulated Indicators
N = 20

Indicator Type	Mean Number of Sec. Per Trial	Difference in Time Between Indicators and t Values for these Diff. (in paren.)	
		Dial, Rotating Scale	Direct Reading Counter
Dial, Rotating Pointer	0.88	57.79 (5.53)*	52.82 (9.23)*
Dial, Rotating Scale	1.46		4.97 (0.60)
Direct Reading Counter	1.41		

* t = 3.850, P .001

Results:

The mean times and percent of errors for this experiment are summarized in Figure 2 and Table I. The latter includes "t" values for intercomparisons of response time among the three indicator designs. Average times for check reading and making of an appropriate switch movement were 1.41 seconds and 1.46 seconds respectively for counter and rotating scale type indicators and 0.88 second for the rotating pointer type indicator. Differences in performance between counters and rotating scale indicators were not appreciable but time and errors in check reading the rotating pointer type indicators were considerably less than for the other two indicator types. This superiority of the rotating pointer in terms of response time is significant at the .001 level of confidence. That is, values of "t" as large or larger than those obtained would be expected to occur by chance only once in a thousand times.

From examination of the data it appears that the direction of switch movement did not have a significant effect upon the results. There was no demonstrable difference in the performance of subjects who moved the switch to the right for a 'same' response and those who moved the switch to the left.

The error data, 14.3 percent errors for moving scale type indicators, 15.3 percent for counter type indicators and 8.6 percent for moving pointer type indicators, supports the premise that conditions producing maximum precision generally produce maximum speed. Only about half as many errors were made on the rotating pointer type indicator as were made on the other two indicator types.

III. EXPERIMENT NO. II

Speed and Accuracy of Check Reading Numbers Ranging from Two to Seven Digits

Purpose:

Experiment No. 2 was conducted in order to compare subjects' performance in check reading two-, three-, four-, five-, six- and seven-digit numbers. Speed and accuracy in detecting differences between verbally and visually presented numbers was measured.

Apparatus, Procedure and Subjects:

The displays evaluated in this experiment were 9- by 13-inch black cards in the center of which appeared single numbers of lengths varying from two to seven digits. The stimulus numbers were prepared by pasting prints of glossy finish photographs on the card surfaces. White numerals 3/16" in height were used in conformity with standards recommended by the Army-Navy NRC Vision Committee for research on visual displays. All features of the displays were held constant except for the critical variable of number of digits making up the numbers.

With slight modification to accommodate the new type of stimulus material, the exposure apparatus described in Experiment No. I was adapted for use in this second experiment. The simulated instrument panels previously used were replaced by the stimulus cards, held in place by a spring lever mechanism and interchanged at each trial,- a single number appearing on each card. The subject's task was to listen to a verbal presentation of the number spoken by the experimenter and to compare it with one appearing in the exposure apparatus immediately following. Numbers were read as discrete figures: "2-7-3" rather than "two hundred and seventy-three." Approximately two seconds intervened between the auditory and visual stimuli. If the two numbers were the same, the subject responded by throwing the toggle switch to the left, and if different, to the right. Two thirds of the examples given required "different" responses. As formerly, the experimenter was informed of the subject's choice through a group of signal lights to the rear of the panel. In case of error the shade remained up until the correct response was made. A standard electric timer measured the interval between the raising of the shade and the correct response so that in case of an incorrect response the time recorded included the time required to recognize and correct the error, beyond the time of the initial response.

Selection and arrangement of digits comprising separate test items were subject to rather extensive counterbalancing procedures to insure results free from the influence of particular combinations and arrangements of digits. No digit followed itself or appeared more than once in any digit series. In no instance did the spoken and printed numbers differ from one another in more than one digit, nor was the deviation ever greater than unity in the deviating digit. The position of the deviating digit in the series was systematically varied. In order to maintain as much unity as possible among the various sized numbers, the same combinations of digits appeared in examples of each size. Thus 12 seven-digit numbers were derived by suffixing succeeding digits to 12 basic two-digit numbers until the seven-digit length was reached. The three-digit number derived from the basic two-digit number 43 might be 843 and the four digit number 7843, etc. Post-test comparisons revealed no inherent differences in difficulty among these various digit sequences.

With 12 examples of numbers of each size, a total of 72 problems was obtained. After a brief practice session, these were presented in random order in a single experimental session.

The ten male subjects serving in the experiment were recruited from among personnel of the Aero Medical Laboratory, Wright-Patterson Air Force Base. Five had some familiarity with the experimental technique through participation in previous check-reading studies. All had uncorrected normal vision.

Results:

The average response times for each of the six number sizes, obtained by averaging means for all subjects on all of the 12 basic digit combinations, are recorded in Table II, along with the percent of responses in error. As

TABLE II

Time and Errors in Check Reading Numbers Ranging from Two to Seven Digits in Length
N = 10

	Mean Number of Seconds Per Trial	% of Total Trials In Error
Two-Digit Numbers	0.64	2.5
Three-Digit Numbers	0.75	7.5
Four-Digit Numbers	0.86	10.0
Five-Digit Numbers	1.04	11.6
Six-Digit Numbers	1.28	12.5
Seven-Digit Numbers	1.45	10.0

TABLE III

Significance of Differences in Average Time (in Seconds for Check Reading Among Six Sized Numbers
N = 10

Length of Number		3-Digits	4-Digits	5-Digits	6-Digits	7-Digits
2-Digits	Diff.	0.11	0.22	0.40	0.64	0.81
	"t" *	6.68	5.64	8.27	10.3[illegible]	10.72
3-Digits	Diff.		0.11	0.29	0.53	0.70
	"t"		2.37	5.27	9.57	9.22
4-Digits	Diff.			0.18	0.42	0.59
	"t"			3.85	8.88	8.17
5-Digits	Diff.				0.24	0.41
	"t"				5.0[illegible]	8.18
6-Digits	Diff.					0.17
	"t"					3.19

* Values of "t" above 3.25 would occur by chance less [illegible] 1 time in 100.
Values of "t" above 2.26 would occur by chance less than [illegible] times in 100.

may be seen from the table, the average time of .63 seconds required to check read two-digit numbers increased to an average of 1.45 seconds for the seven-digit numbers. It is apparent that a direct relation existed between the length of a number and the time required to check and make a discriminatory response to that number. A progressive steplike increase in mean response time occurred with each one-digit increase in the length of a number. These differences in response time were all reliable beyond the 5% level of confidence (Table III). In fact, all but two would occur by chance only one time in a hundred if no actual differences existed.

The error data, as shown in Table II also indicated a progressive increase in difficulty as size increased, varying from 2-1/2 to 12-1/2 percent of all responses for any one number size. These results are less consistent than the time differences. as might be expected from the small numbers being compared. About one eleventh of all responses made were in error.

IV. DISCUSSION OF RESULTS

Close inspection of the task confronting the subject in check reading each of the three instrument panels of Experiment No. I corroborates the results obtained. The general superiority of rotating pointers over rotating scales for check reading tasks (as shown in Experiment I) can probably be attributed to the difference in the cues provided in the two cases. Change in indication of a rotating pointer dial alters scale and pointer relationships but all that is necessary to observe, when merely checking, is change in angular position of the pointer. In the case of the rotating dial, however, check reading probably requires reading of one or more of the numerals on the scale.

In a tachistoscopic study of dial design by Sleight (8), quantitative readings (i.e., noting full numerical value of the indication) were more accurately obtained from open window type indicators (horizontal drum rotating behind fixed pointer) after brief exposures than from either circular or semi-circular dials (rotating pointers) or from vertical or horizontal scales (moving pointers). The discrepancy between these findings and the findings of the present study which favor the rotating pointer type indicators can be explained by careful definition of the nature of the task. Actual numerical readings rather than mere evidence of change was the information sought by Sleight's subjects. Mere observation of pointer displacement was of no value. In fact, assurance of a constant pointer position from trial to trial, thus obviating search for the pointer location on each new trial, reduced by one step the task of obtaining quantitative readings from a fixed pointer indicator over the task of obtaining the same reading from a rotating pointer indicator.

It is only logical to expect that the simpler an indicator is designed, within the limits of desired accuracy, the less difficulty there will be in reading it. All actual comparisons have shown that direct reading counters present numerical information with minimum possibility of interpretation or perception errors (2) (3). However, in the case of check reading, this indicator may be lacking in certain valuable cues provided by changes in scale and pointer relationships. In aircraft especially, it is common for indicators to fluctuate continuously from static settings. Unlike scale type indicators, a fluctuation of even one mile in a counter type indicator would alter the appearance of the indicator considerably. The difficulty in distinguishing these marginal fluctuations from significant deviations is a major reason why counters show up poorly on check reading tasks in comparison with the rotating pointer type indicators.

With regard to the proper number of digits to be used in a counter to obtain satisfactory results, the criterion is, of course, the precision required. Even an increase in precision of three beyond two digits costs appreciably in speed and accuracy of check reading.

These observations demonstrate the extreme importance of defining the exact conditions of the task and of confining inferences to the data. Relatively peripheral factors such as the comparative number or spacing of scale markings, for example, might operate to significantly change the position of any one indicator. It should be pointed out that at no point in either study of this report was the subject required to read an indicator which was changing from one value to another. Constant change in indication might be expected to influence the readability of some indicators more than others. It should also be noted that in any actual flight situation, check reading is only one of several similar operations. Retention of a numerical reference over a period of interpolated activity may well be less perfect than retention of pointer position relative to itself over the same period.

The superiority of the rotating pointer indicator (with readings centered in the left dial quadrant) accords with findings of related experiments for direct presentation of data when indicators are merely to be checked for alignment at the reference setting (4). It is evident that the most common aircraft instrument, a rotating pointer on a circular dial, is an excellent type of indication for check reading purposes.

V. CONCLUSIONS

From the findings of these experiments, it may be concluded:

1. In check reading a row of instruments (i.e., determining significant deviations of one indicator in a row of similar indicators fluctuating rapidly from precise reference values), rotating pointer indicators with the reference value centered in the left dial quadrant are in general superior to rotating scale indicators with fixed pointers in the left dial quadrant and to direct reading counters.

2. The speed and accuracy with which singly presented numbers may be check read increases directly as the number of digits decreases from seven to two digits. These results are related to the performance to be expected in the check reading of direct reading counters.

BIBLIOGRAPHICAL REFERENCES

1. Armed Forces-NRC Vision Committee Standards to be employed in research on visual displays. October 1947, Revised March 1950.

2. Chapanis, A. The relative efficiency of direct-reading counters and scales for target indication from radar equipment. Minutes and Proceedings of the Army-Navy-NRC Vision Committee. 18th meeting, 14-15 January 1947.

3. Grether, W. F. The effect of variation in indicator design upon speed and accuracy of altitude readings. AMC Engineering Division Memorandum Report No. TSEAA-694-8, 2 September 1947.

4. Grether, W. F. and Connell, S. C. Psychological factors in check reading of single instruments. USAF Air Materiel Command Memorandum Report No. MCREXD-694-17A, 20 September 1948.

5. McGehee, W. Comparative study of pilot fatigue resulting from extended instrument flight using the standard AAF and British instrument panels. Final Report, Project TED No. ATL-R 601, U. S. Naval Air Station, Atlanta, Georgia.

6. Milton, J. L., Jones, R. E., and Fitts, P. M. Eye fixations of aircraft pilots, II. Frequency, duration, and sequence of fixations when flying the USAF instrument low approach system (ILAS). USAF Air Materiel Command Technical Report No. 5839, October 1949.

7. Sleight, R. B. The effect of instrument dial shape on legibility. J. Appl. Psychol., 1948, 32, 170-187.

8. Warrick, M. J. and Grether, W. F. The effect of pointer alignment on check reading of engine instrument panels. AMC Engineering Division Memorandum Report No. MCREXD-694-17, 4 June 1948.

9. White, W. J. The effect of dial diameter on ocular movements and speed and accuracy of check reading groups of simulated engine instruments. USAF Air Materiel Command Technical Report No. 5826, [illegible]

CADO CONTROL NO.: (N.A.) 129800

US CLASSIFICATION: UNCLASS

ATI NO.: 85 523*

OA NO.: (NONE)

TITLE:
SOME VARIABLES AFFECTING INSTRUMENT CHECK READING
(AF TECHNICAL REPORT). AUG 1950. 11PP.
63 2

AUTHOR(S):
CONNELL, SHIRLEY C.

ORIGINATING AGENCY:
AIR MATERIEL COMMAND, ENGINEERING DIV., DAYTON, O.

FOREIGN TITLES:
(N.A.)

PUBLISHED BY:
AMC, WRIGHT-PATTERSON AIR FORCE BASE, DAYTON,

PUBLISHING NO.:
AF-TR-602

TRANSLATION NO.:
(N.A.)

AD-A800 380

PREVIOUSLY CATALOGED AS:
(N.A.)

NTIS, Auth: AMRL ltr, 27 Aug 74

ATI- 85 523
DIVISION (None)
ORIG. AGENCY NO. (None)
PUBLISHING AGENCY NO. AF-TR-6024

TITLE: Some Variables Affecting Instrument Check Reading (AF Technical Report)

AUTHOR(S) : Connell, Shirley C.
ORIG. AGENCY : Air Materiel Command, Engineering Div., Dayton, Ohio
PUBLISHED BY : AMC, Wright-Patterson Air Force Base, Dayton, O.

DATE	U.S. CLASS.	COUNTRY	LANGUAGE	PAGES	ILLUSTRATIONS
Aug' 50	Unclass.	U.S.	English	11	photo, tables, diagr

ABSTRACT:

Two studies were conducted, in one of which subjects check read panels of simulated instruments and in the other singly presented numbers ranging in size from two to seven digits. In the first study, panels of four identical simulated indicators, all aligned at the same setting, were checked for significant deviations from the reference setting. This simulated part of the task of pilot or flight engineer in checking the engine instrument panel of a four-engine airplane. Average time and percent of errors of 20 subjects in detecting significant deviations in setting among four circular dials with rotating pointers were about half as great as time and errors in detecting deviations among four direct reading counters or indicators with a scale rotating behind a fixed pointer. In the second study, the speed and accuracy increased directly as the number of digits decreased from seven to two.

DISTRIBUTION: Copies obtainable from CADO.

DIVISION: Aviation Medicine (19)
SECTION: Flight Psychology (2)

SUBJECT HEADINGS: Instrument displays - Psychological aspects

CADO TECHNICAL INDEX