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NAVAL POSTGRADUATE SCHOOL

Monterey, California

THESIS

A COMPARISON OF AUDIO, VISUAL, AND TACTILE WARNING DEVICES IN A SIMULATED FLIGHT ENVIRONMENT

by

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March 1983

Thesis Advisor: D. E. Neil

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
A Comparison of Audio, Visual, and Tactile Warning Devices in a Simulated Flight Environment

5. TYPE OF REPORT & PERIOD COVERED
Master's Thesis
March 1983

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
Robert Joseph Larkin

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Naval Postgraduate School
Monterey, California 93940

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
Naval Postgraduate School
Monterey, California 93940

12. REPORT DATE
March 1983

13. NUMBER OF PAGES
44

14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)

15. SECURITY CLASS. (of this report)

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Tactile, visual, audio, t-statistic, flight, vibratactile

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
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DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-014-6601

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) alpha

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A Comparison of Audio, Visual, and Tactile Warning Devices in a Simulated Flight Environment

by

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
March, 1983

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ABSTRACT

An experiment was performed in which fifteen subjects responded to three separate warning devices; an audio, visual, and tactile device. Reaction times to each randomly presented device were measured while each subject was simultaneously engaged in piloting a personal flight simulator. Instructions to the subjects were continually presented visually on a TV monitor and verbally through a set of earphones. The mean reaction times for each device were compared using a difference of means t-test. The results showed that the tactile device produced significantly faster reaction times at the $\alpha = .01$ significance level. This led to the conclusion that a tactile warning device could be effective in a flight environment where visual and auditory senses can easily be overloaded.

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I. THE PROBLEM

A. BACKGROUND

The prevention of aircraft accidents has been the aim of countless private industry and government studies. A result has been the reduction of the fatality risk of air travel by more than one-half in the past 15 years [Ref. 1]. Of major concern lately has been the large percentage of flight accidents which have been attributed to human error. It is this problem of human factors involvement in aircraft mishaps that frequently tends to negate the material and technological advances in modern high performance aircraft. One government study states that 70 percent of all civil aviation incidents during a recent five-year period were attributable to human error, leading to the claim that human factors is clearly lagging behind technology [Ref. 2].

In a report on reducing human error in Navy aviation mishaps, Layton [Ref. 3] states that the most involved of the human operator functions is the task of the aircraft pilot and the single item that may be of most benefit and conversely of most detriment is the cockpit/instrumentation design. The evolution of cockpits and instrumentation until most recently has been one of fitting the man to the machine instead of vise-versa. The manner in which gauges, switches, and controls were placed inside the cockpit historically considered human engineering only to the extent that they were legible, had useable format, and were located as near the center of the pilot's cone of regard as their importance dictated [Ref. 4]. Modern engineering methods include the use of anthropometric data and the study of psychological factors previously not appreciated.

Pioneer aviators relied heavily on their physical senses for information and had few instruments or gauges to verify their interpretation. As the performance characteristics of aircraft increased, more information was needed to monitor the indifferent systems and accompanying technology was able to provide appropriate displays within the cockpit. The advent of an all-weather flying capability required even more instruments as did the increasing complexity of the control systems of each new generation of aircraft. Consequently, much of our effort has been to ensure that every bit of information which can be sensed or computed by the aircraft system is displayed to the pilot whether he needs it or not.

Integrated instrumentation cockpit plans have been proposed to overcome the problem of not having enough room in the cockpit for the ever increasing array of gauges and displays. Schultz [Ref. 5] states that while there exists a highly advanced state of development of the complex technology of information processing, gaps still exist in the transfer of information to the pilot of a jet aircraft. The pilot does not have sufficient information to quickly identify certain potentially dangerous flight conditions. Part of this gap stems from the fact that too much information is available. Sells and Berry [Ref. 6] have suggested that it is known from recent studies that the human brain is limited with respect to the amount of information with which it can deal in a given period of time. This restriction in information transfer is dependent upon the channel over which it travels. Cruise [Ref. 7], in a study on aviation psychology, stated that the visual sensing system is the major factor in acquiring the information necessary for the monitoring and control of high performance aircraft. Therefore, it is no surprise that most cockpit display systems are presented visually and errors of misinformation or misinterpretation occur as the visual sense becomes overloaded as a channel of information transfer.

B. PURPOSE

To propose and test a system which may aid in overcoming this channel overload condition and allow the transfer and correct interpretation of critical information was the purpose of this experiment. A possible solution to be tested was the use of a tactile warning device to provide information to the pilot. It was hypothesized that presentation of information via the cutaneous sense may result in a significantly reduced reaction time during conditions of visual and auditory loading.

In addition to operational instrumentation, tactical displays, and communications systems, pilots are often confronted with a myriad of audio and visual warning devices. These warnings or alarms are intended to alert the operator that some component of the system is malfunctioning or in jeopardy. They can range in seriousness from minor equipment malfunctions to life threatening situations. Overloading of any sensory receptor increases decision reaction time and the probability of operator error [Ref. 8]. In a weapons system, such as a military aircraft, space limitations also limit the number of light emittors that can be placed in the operator's field of view. Sharp [Ref. 9] demonstrated response time to warning lights was significantly longer when the lights were 57 degrees or more off the center plane while the operator was involved in an operational task.

In terms of accidents involving "pilot error", Fitts and Jones [Ref. 10] found that 14 percent of these errors were due to incorrect signal interpretation. This included failure to notice warning lights and confusing one warning signal with another. It is reasonable to conclude that the mean and variance of reaction times to critical warning signals can have serious implications for operator and equipment well-being.

Concerning possible alternative sensors, Cruise [Ref. 11] says that aural and other methods are useful as ancillary sources in the process of information transfer but mainly as corroborative efforts. Huchingson [Ref. 12] also states that under certain conditions the use of auditory signals is preferable to visual displays but that formalized tactual coding systems have limited application to aerospace systems. However, several authors have had great success in using tactile sense as an alternative channel of information processing, particularly in an environment of visual and auditory overloading.

Tactile sense is generally thought of as the sense of touch implying an active attempt to transfer information by feel. Of potentially more interest is the passive processing of information through stimulation of the skin commonly referred to as cutaneous stimulation. Many authors have noted that cutaneous stimulation is an effective method for eliciting a desired response. Van Cott [Ref. 13] points out that under laboratory conditions, the mean reaction time for cutaneous stimulation is faster than any other sense. Tactile stimulation has been employed successfully as an alternative sensory mechanism for the blind [Ref. 14] and the deaf. McRae [Ref. 15] summarizes,

> "There is no doubt that the tactile nervous system has the ability to process some information normally received through the auditory system...It is certainly possible in the most elementary case to conceive of at least giving certain alerting signals through the tactile senses."

Hawkes [Ref. 16] takes this a step further in assessing that tactual stimulation could be used to give any kind of warning or alerting signal.

Sumby [Ref. 17] conducted an experiment wherein he compared separately reaction times for visual, auditory and tactile stimuli. He found that mean reaction times were not significantly different between the three. Although his experiment did not provide a primary task, he concluded,

> "...with the other senses highly preoccupied during the critical phases of a flight, or other system operation, this result suggests that vibratactile signals could be profitably incorporated into such systems to be used as possible warning devices or other low information messages."

Not surprisingly, Glucksburg [Ref. 18] demonstrated that reaction times to visual, auditory, and tactile stimulation are slowed when an operator is confronted with a primary task; in this case, rotary pursuit tracking. It is interesting to note that the primary task did not suffer with the presentation of tactile or audio stimuli, but was adversely affected when the subject was required to respond to visual stimuli.

A review of the current literature does not suggest that there exists on optimal apparatus for tactile stimulation. Various devices have been used, from the very simple mechanical vibrator type used by Heard [Ref. 19] to the more complicated tactile vocoder (multiple stimulus audio interpreter) used by McRae [Ref. 20] for tactile communication. Most applied experiments have employed the vibratactile type device, although Sumby [Ref. 21] utilized electrical stimulation with successful results. Indeed, the adverse psychological effects of a shock stimulus may be offset by its advantages. The electrical pulses can be easily varied with a resulting high degree of control over the parameters of stimulation. Reportedly, procedures have been developed for painless electrical stimulation over much of the body surface [Ref. 22]. Researchers have also developed sensitivity thresholds for various parts of the body; however, in virtually all applied experiments dealing with warning stimuli, the devices have been placed on areas most likely to be accessible in practical application.

In the area of applied research, Ballard and Hessinger [Ref. 23] developed a workable thumb-mounted vibratory device to convey pitch and roll information to aircraft pilots. Variable frequencies alerted pilots to on-off course conditions. Burrows and Cummings [Ref. 24] engineered an experimental aircraft control column grip which vibrated when a simulated emergency condition was encountered. The reaction time from this stimulus was compared with that of a warning light placed directly in front of the subject. With a sample of 12 pilots the results indicated there was no statistical difference in the mean reaction time between the two stimuli. Heard [Ref. 25] conducted experimental research to test the theory that, under conditions of auditory and visual loading, the mean response time to a secondary vigilance task is dependent upon the sense being stimulated. The results indicated the mean reaction time of a tactile stimulus was fasted among the three senses (tactile, auditory, visual) being investigated. Although the data proved to be statistically significant, the mean reaction times of the three stimuli were quite close. For this reason, the decision as to which stimulus would be most appropriate for a warning device cannot be made on mean reaction time alone. Variance in reaction times is also important, in that if mean reaction times are similar, the most consistent stimulus would be preferred.

The present experiment was designed to test the hypothesis that under conditions of visual and auditory loading, the mean reaction time to a secondary task would be less for a tactile stimulus compared to a visual and auditory stimulus and that the reaction to a tactile stimulus would be subject to less variance.

II. METHOD

A. SUBJECTS

The subjects for the experiment were fifteen male military officer students from the Naval Postgraduate School. The fifteen students were all experienced in private or military aviation. All were volunteers and received no compensation for participation.

B. STIMULI AND APPARATUS

Subjects were seated at a table in a sound reduced booth facing an ATC-510 personal flight simulator made by Analog Training Computers, Inc. The flight simulator is shown in Figure 1 and includes a pair of foot operated rudder controls not shown. External to the simulator were two devices used to produce three sensory stimuli as simulated warning devices. A warning horn and a warning red light were located directly in front of the subject next to the magnetic compass on the personal flight simulator. Figure 2 illustrates the location of all equipment necessary to the subject during an experimental run.

The tactile warning device developed for this experiment differed from most of the designs of earlier experiments. Rather than using a transducer to relay vibratory signals, it was decided that a low current electrical transformer would

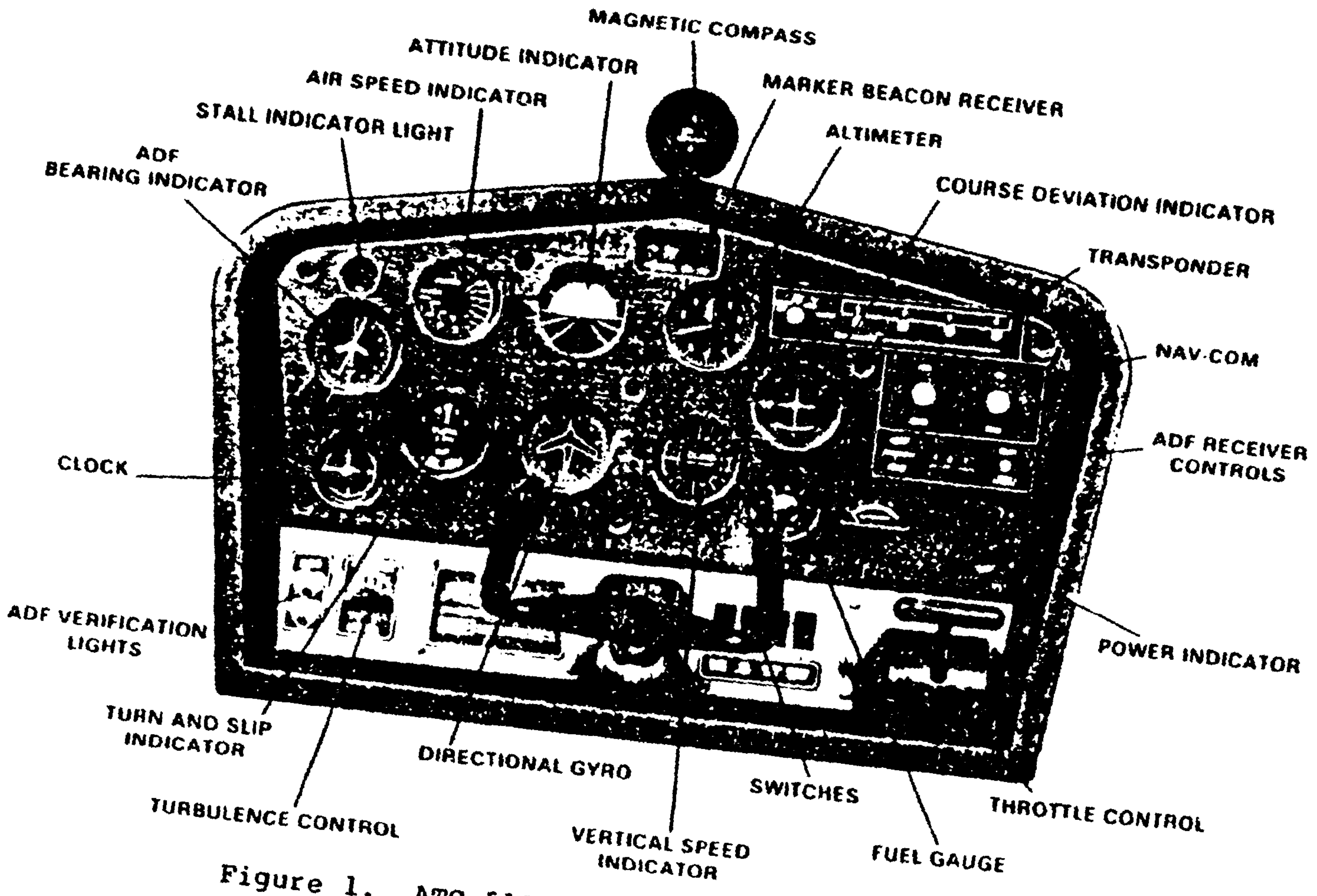

Figure 1. ATC-510 Personal Flight Simulator

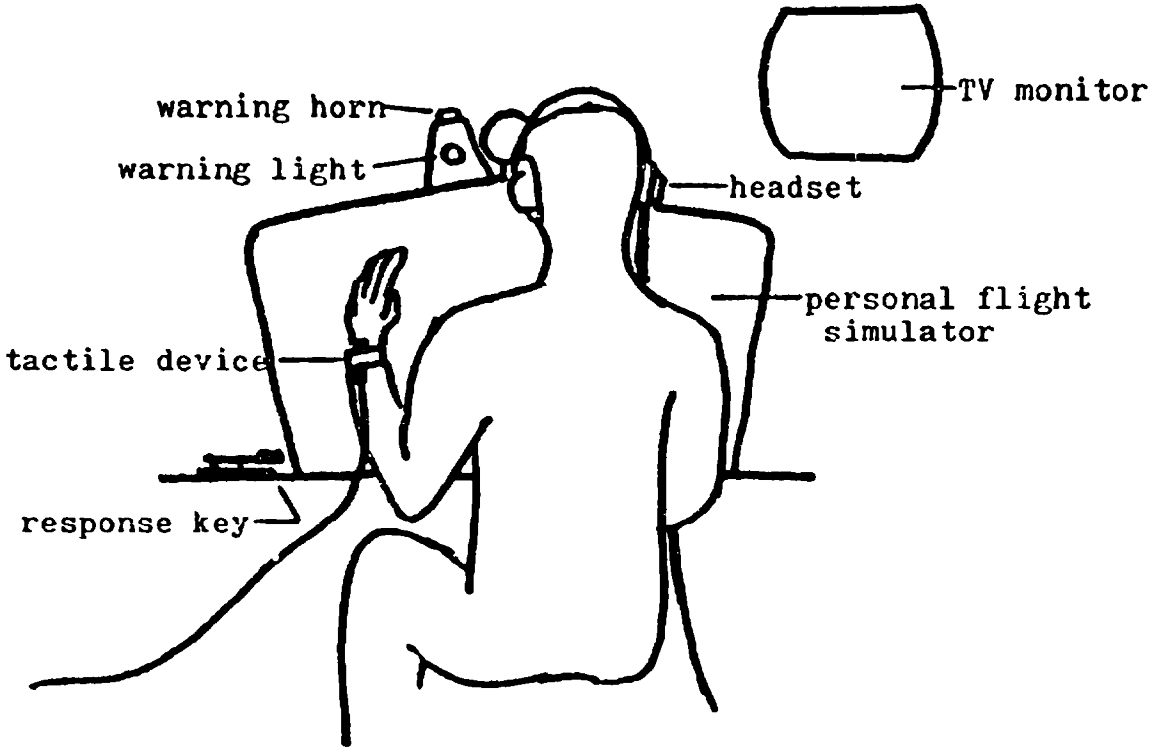

Figure 2. Experiment Apparatus

provide an acceptable stimulus while still providing maximum freedom of movement. The design consisted of a small piece of plexiglass (approximately one inch by one inch) with two small screws mounted flush to it to serve as electrical conductors. The two screws were approximately one-half inch apart and were connected to a coil system where the strength of the shock could be adjusted. The device was then attached to the back of the subject's left wrist with an elastic band. The intensities of each of the warning devices (light, horn, shock) were fixed at a constant setting for all subjects with the intent of providing a uniform discernible and unambiguous signal.

A response key was positioned on the table top just to the pilot's left side of the simulator. A stereo head set was provided for the subject to receive verbal commands from a taped audio cassette instructing him to perform various simulated aircraft maneuvers. A black and white television monitor was positioned to the subject's right and elevated to just above eye level. Visual commands were given over the TV in the form of written messages on video tape to provide additional visual loading.

The flight simulator instrument panel contained all the instruments necessary for an experienced aviator to practice simulated flight. Physical inputs were required to be made on the yoke, rudder pedals and a throttle control. In addition, several communication and navigation control switches were required to be turned to new frequencies or changed to new positions.

C. PROCEDURE

Each subject was seated in the booth and given verbal instructions for his first task, which was to fly the simulator in response to commands presented through the headphones and on the TV. He was given a ten minute familiarization brief on the personal flight simulator which included short maneuvers to provide a feel for the simulator controls. All controls and switches were discussed as to location and purpose. He was told that his performance in adhering to the visual and verbal commands would be monitored and he was to respond to the best of his ability. Before the experiment began, he was instructed in his second task which would be performed simultaneously with the first. He was to respond to simulated warnings presented by the warning horn, warning light, or tactile device. He was told that when a warning appeared on any of the devices he was to press the response key as quickly as he could. The warning signal would then cease when the key was depressed and he could return to his first task. The timing was started when the signal was initiated through the device and stopped when the response key was touched. The subject was given a demonstration of each of the devices and the response key.

The subject was told that the three warning devices would appear at random times and order throughout his simulated flight. Figure 3 shows the time and order of the appearance of each device which were presented four times apiece.

TIME	SENSOR
0:32	LIGHT
2:56	LIGHT
4:32	LIGHT
6:02	HORN
7:21	SHOCK
8:56	HORN
10:44	SHOCK
12:35	SHOCK
13:52	HORN
15:24	HORN
17:25	SHOCK
19:22	LIGHT

Figure 3. Order and Occurrence Times for Warning Stimuli

He was given a final brief outlining a scenario in which he would be under the positive control of an air controller who would vector him through various course, speed, and altitude changes in order to position him for a simulated approach to an airport.

The subject was to monitor both his headphones and TV monitor for all commands. He was told that there would be no conflict between the two sources of instructions. The path of his simulated flight is shown in Figure 4 and a transcript of his audio tape is located in Appendix A. The messages that were presented visually on the monitor are shown in Table I with their times of occurrence.

TABLE I

VISUAL COMMANDS AND TIMES OF OCCURRENCE

TIME	MESSAGE
0:41	TURN TRANSPONDER TO STANDBY
2:13	TURN MARKER BEACON ON
5:06	CHANGE NAV FREQ TO 110.9
8:19	TURN TRANSPONDER TO 1200
12:43	TURN ROTATING BEACON ON
14:08	TURN LANDING LIGHT ON
16:21	SWITCH TO ADF FREQ 320
19:26	CHANGE COMM FREQ TO 130.2

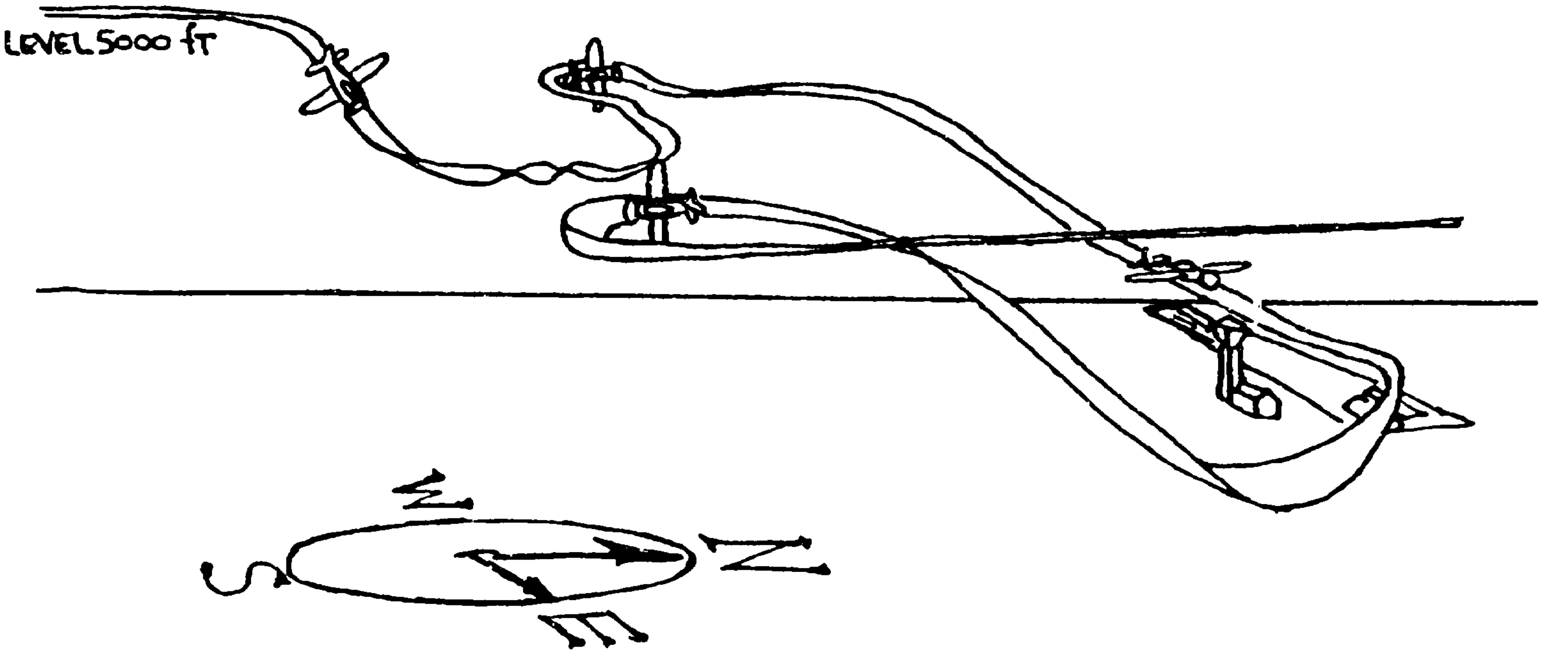

Figure 4. Simulated Flight Path of Instrument Trainer

D. DESIGN

Data from the experiment were analyzed pairwise by testing the difference between two sample means when their variances were unknown using a t-statistic. Two cases are possible concerning whether the two variances are equal or not equal. When both populations are normal and the samples are independent, a standard F-distribution can be used in comparison with the ratio of the unbiased estimates of variance computed from the samples. This comparison with the F-distribution tests the hypothesis that the variances are equal.

III. RESULTS

Table II is a summary of the results of this experiment.

TABLE II

MEAN RESPONSE TIMES BY SUBJECTS AND SENSOR TYPE

SUBJECT	LIGHT	HORN	SHOCK
1	5.123	1.415	0.975
2	2.375	1.170	0.743
3	2.958	1.253	0.713
4	3.230	0.920	0.790
5	1.550	1.258	0.915
6	1.188	1.320	0.800
7	0.645	0.563	0.393
8	5.815	1.288	1.068
9	2.355	1.130	0.655
10	5.603	1.745	0.935
11	1.003	0.973	0.785
12	1.165	1.108	1.088
13	0.883	1.433	0.535
14	1.313	1.198	1.108
15	2.111	1.393	0.895
MEAN	2.554	1.211	0.827
S.D.	1.866	0.269	0.203
VAR.	3.482	0.072	0.041

These results are presented graphically in Figure 5. The computations shown in Tables III and IV were done after the data was transformed using the square root function. This was done to reduce the skewness and make the data sets more symmetrical [Ref. 26].

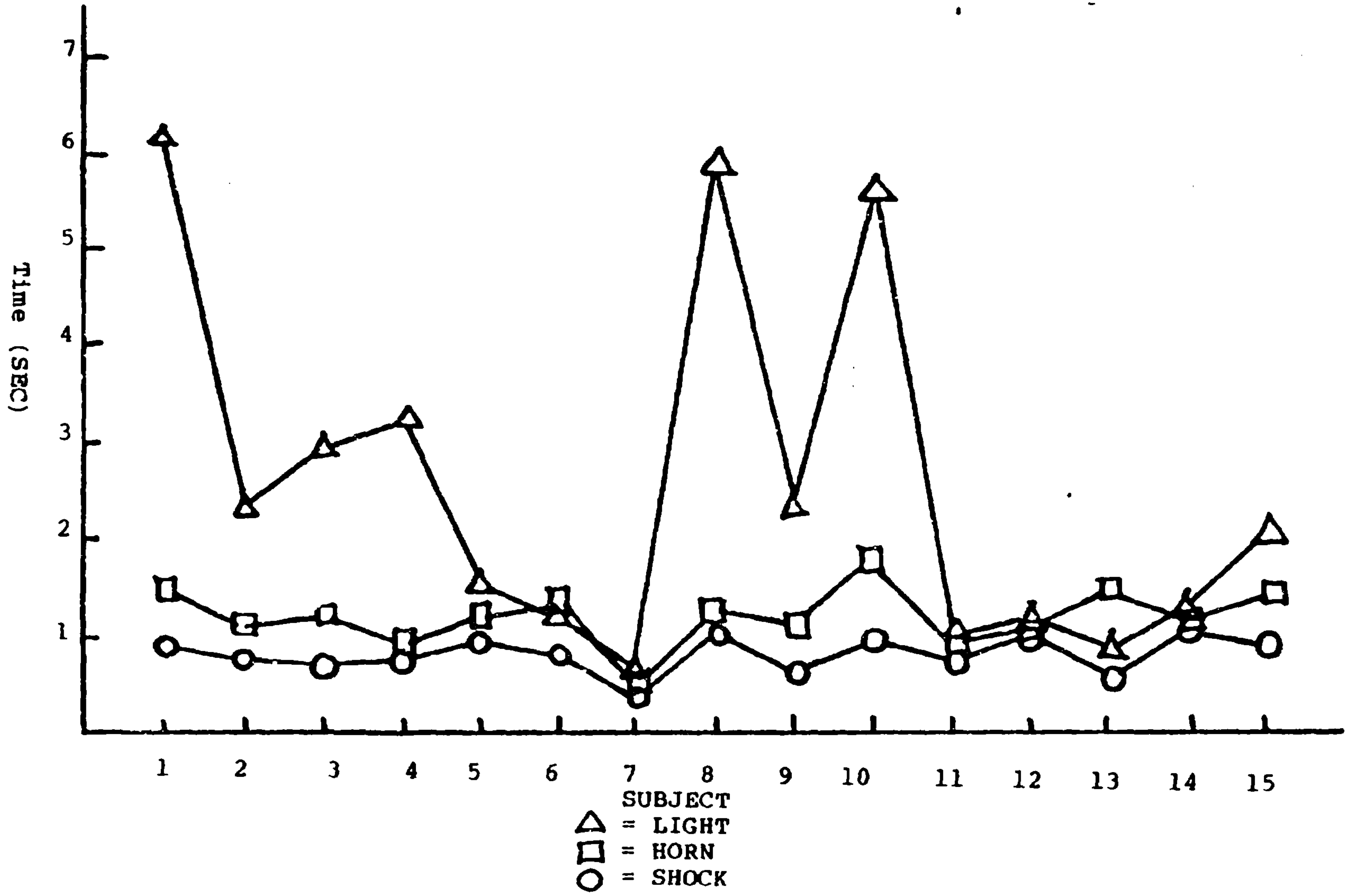

Figure 5. Mean Response Time by Subject and Sensor

The results in Table III, which uses an F-distribution to test the hypothesis that the variances are equal, indicates that the variance in response times for the light is significantly greater than the variance associated with either the horn or shock device.

It was because of this result which supported the hypothesis of unequal variances that the analysis of variances [Ref. 27] (ANOVA) methodology, which assumes equal variances, was not used.

TABLE III

COMPARISON OF SAMPLE VARIANCES USING F-DISTRIBUTION

	D.F.	SAMPLE VARIANCE	F	SIGNIFICANCE LEVEL
LIGHT VS. HORN				
LIGHT	14	0.304	19.0	0.000*
HORN	14	0.016		
LIGHT VS. SHOCK				
LIGHT	14	0.304	21.7	0.000*
SHOCK	14	0.014		
HORN VS. SHOCK				
HORN	14	0.016	1.16	0.394
SHOCK	14	0.014		

* - significant at $\alpha = 0.01$

This observation suggested the use of the Aspin-Welch t-test [Ref. 28] to test whether there is a significant difference between the mean reaction times for light and those for the horn or shock device. This special test is used for testing the difference between two sample means when the population variances are unknown but assumed to be not equal. The test of variances for the horn versus shock does not show a significant difference and therefore the more general paired sample t-test for differences [Ref. 29] was used for the horn versus shock case in Table IV. This test does not require an assumption of equal variances or independence between data sets.

The results in Table IV indicate that there is a significant difference between the means for all three cases.

TABLE IV

COMPARISON OF SAMPLE MEANS USING t-DISTRIBUTION

	D.F.	SAMPLE MEANS	t	SIGNIFICANCE LEVEL
LIGHT VS. HORN	16			
LIGHT		1.507	2.89	0.005*
HORN		1.085		
LIGHT VS. SHOCK	15			
LIGHT		1.507	4.16	0.000*
SHOCK		0.902		
HORN VS. SHOCK	14			
HORN		1.085	5.46	0.000*
SHOCK		0.902		

* - significant at $\alpha = 0.01$

This result is in keeping with Heard's findings [Ref. 30] that the response time will be a function of the type warning device and that the tactile device provides the fastest mean reaction time. Though Heard used a vibratactile device, it also agrees with the conclusion reached by Swink [Ref. 31] that an electro-pulse tactile device produced faster reaction times than either audio or visual devices.

IV. DISCUSSION

The attempt of the design of experiment was to provide a reasonable aircraft flight simulation chamber in which all confounding variables were eliminated or held constant so that an objective test of three dissimilar warning devices could take place.

The first assumption of the design is that the visual and audio loading of the primary task approximates the level of loading that takes place in a real flight. If not, how would this affect the results? The visual and verbal commands that constitute the task of flying in the experiment provide a constant level of loading for an experienced pilot. That loading may vary slightly from pilot to pilot depending upon how long he had been out of a flying environment, but the response times for each of the four replications for each device are considered to be based on constant loading for that individual. Plots of each of the subject's responses for each device were looked at over time and there did not appear to be any pattern associated with learning or deviations in loading level. Therefore, experience differential between subject pilots was not felt to contribute to bias in the comparison of warning device response times.

Under the assumption that the aircraft is single-piloted, the level of loading falls short of that actually encountered in a flight. The constant requirement to balance visual information received outside the cockpit and a need to monitor all displays and warnings within the cockpit provide a level of visual loading that is only approximated in the experiment. A pilot's ability to balance the visual requirements inside and outside the cockpit depend largely on the mission of the aircraft and the phase of flight. A study done by Lovesy [Ref. 32] on helicopter ergonomic factors used a cine camera mounted in the cockpit with a fish-eye lense to record the pilot's movements. The results showed that when a pilot is performing more exacting tasks of descent or hover near the ground and in a confined area he cannot afford to look inside the cockpit for more than a second or so at a time. This requirement was not reflected in the current experiment. Also, the subject was only required to monitor one warning light placed directly in front of him as compared to the myriad of lights that are placed in an actual cockpit in widely varying positions. Therefore, the significance attached to the light having the greatest response time is probably a conservative result.

The audio loading in the experiment consisted of a series of verbal commands given over a headset. The subject had only to respond to a horn of fixed pitch which was demonstrated to be louder than the verbal commands. In a real flight, the pilot is required to respond verbally to most voice inputs and generally has several noise and vibration sources associated with his aircraft that compete for his auditory attention. Lovesy [Ref. 33] showed that helicopter cabin intercom systems can pick up and amplify the combined sources of noise from aircraft machinery to sufficiently raise over-all noise level at the crew member's ears to a damage risk level. Therefore, the auditory loading was conservative and probably biased in favor of the horn as a warning device. This may have contributed to the result that suggested no difference between the variances associated with the tactile device and the aural warning device. The initial hypothesis was that the tactile device would produce the smallest variance in response times among all three devices, which would agree with Swink's results [Ref. 34].

The next concern is how far the results can be generalized based upon three fixed warning devices. No attempt was made to parameterize the three devices and vary those parameters to find the optimal warning device for its type. They were chosen because they were feasible devices that provided a clear unambiguous signal. Because of the loading bias previously discussed, it is felt that the aural and visual devices provided little or no bias based on their characteristics.

However, the results of the tactile device could have been improved according to discussions with the subjects after their experiment run. Although the shock did not cause physical pain, it did cause an initial reaction to pull back the hand toward the body and away from the response key. Whether this is a result of a physically stimulated muscle or just a psychologically induced startle reflex is not clear but it does appear to have increased the response time according to remarks from the subjects tested. This again could make the results conservative because the tactile response time is already significantly lower than the times associated with visual and auditory devices.

A possible solution to this problem is the use of concentric electrodes which have been reported in research by Tursky, Watson, and O'Connell [Ref. 35] to eliminate burning of the skin, provide increased mobility, delimit the area of stimulation, and reduce unwanted muscle action. This has proven effective in later experiments by Hofmann [Ref. 36] and Schori [Ref. 37].

Other factors that are present in actual cockpit conditions during flight such as vibration, heat or cold could influence the reaction to a tactile stimuli and make it less desireable. These factors were not present in the current experiment and additional research should be conducted to determine their influence.

It is possible that the order in which the warning signals appeared could influence the corresponding reaction times. However, because of the randomization of the order and times of presentation and the assumption of a uniform primary task, this influence is felt to be insignificant.

V. CONCLUSIONS AND RECOMMENDATIONS

It seems clear that in the laboratory conditions of this experiment that a tactile warning device produced the fastest reaction times in accordance with the original hypothesis. Based on these results, many new questions arise and only additional research can produce more answers.

First, it is proposed that additional research make use of existing sophisticated military aircraft trainers which have been proven to provide a realistic environment for simulated flight. This would eliminate the questions concerning any bias in loading.

It is recognized that there may be considerable negative bias against using a shock device. The startle reaction previously discussed could result in an unsafe condition if actually performed in a real flight. However, this response could possibly be minimized through the use of concentric electrodes. It is also felt that the tactile device should be tested for application on the nape of the neck in conjunction with the pilot's helmet. There are electrical cords already located at the base of the helmet for communication equipment and this would eliminate the potentially hazardous situation caused by attaching wires to the hand which could become entangled in the control systems.

These advantages would seem to offset the fact that the back of the neck is not as sensitive to vibratory input as the top side of the forearm [Ref. 38]. The neck has been utilized without problems in experiments conducted by Hofmann and Schori [Ref. 39] in which they employed a variable intensity electro-pulse tactile stimulus.

Finally, under what conditions or scenarios can the advantages gained by a tactile device be best exploited? How much information can be transferred and can the pilot make proper use of the increased decision time given a decrease in reaction time? One scenario envisions its use as a low altitude warning indicator particularly for helicopters with night overwater missions. The response to that particular warning would be to immediately pull collective to increase power thereby increasing altitude. A five second improvement over the time it takes to decode the warning signal to initiating the proper response can mean a difference of 50 feet which is critical when you operate routinely below 200 feet.

It could also be used as an unsafe gear indicator. Pilots of aircraft with retractable gear have the continuing problem of remembering to put the landing wheels down and for varying reasons, generally related to distractions, a small percent forget this crucial and timely step. This problem also brings up a related concern that some investigators refer to as mind-set. This occurs when the individual is so positive that he has no malfunction that he can look at an activated warning light or hear a warning horn and unconsciously ignore it.

Beaty [Ref. 40] has this to say about this common psychological experience,

> "A pilot is particularly prone to 'set' because of the intense concentration necessary for much of his work. He has to train himself in different states of awareness for different instruments and eventualities. In psychology this is known as a 'multiple set' and reaction time naturally increases. Under intense concentration or fatigue, the pilot may shut out altogether all stimuli but one, and he becomes set on one instrument or one course of action."

With a high sensory load situation this experience becomes not only possible but plausible. Additional research could determine whether a tactile stimuli is as prone to 'set' as the audio and visual senses.

Another possible use would be to use it in conjunction with a selector switch which could select different gauges to monitor during different segments of the flight. Different gauges take on different degrees of importance depending on what phase of flight you are in. Of course, this would require additional training to keep from confusing responses depending on where your selector switch was positioned.

In non-aviation areas, in addition to warning signals, or alerting signals, Hennessy [Ref. 41] has worked with the U.S. Army on using cutaneous sensitivity communications for message traffic and privileged one way communications.

APPENDIX A

TAPED INSTRUCTIONS TO SUBJECTS

TIME	INSTRUCTION
00:16	Cherokee 18, Maintain 5000 feet, course 360, speed 120 knots.
00:38	Cherokee 18, turn right to 050.
01:15	Cherokee 18, your heading is 050, altitude 5000 feet, speed 120 knots.
01:41	Cherokee 18, descend to 4500 feet, maintain course and speed.
02:06	American 103, traffic is a Cessna at your two o'clock at 4500 feet.
02:20	Cherokee 18, turn right to 090, continue descent to 4000 feet.
03:34	Cherokee 18, increase speed to 150 knots, you have traffic at your six o'clock.
04:00	Cessna 20, report clear of Airport Traffic Area.
04:29	Cherokee 18, turn left to 340, descend to 3500 feet.
05:00	Cherokee 18, you have traffic moving to ten o'clock.
05:35	Cherokee 18, we'll have to vector you around traffic. Turn right to 360, maintain altitude and speed.
05:50	Cessna 20, maintain 3000 feet, heading 210.
06:35	Cherokee 18, turn left to 330.
07:10	American 103, you're cleared to land.
07:37	Cherokee 18, climb to 4000 feet, maintain course and speed.

09:04 Cherokee 18, turn left to 270, decrease speed to 120 knots, entering Airport Traffic Area.

09:58 Cherokee 18, standby for final controller, reduce speed to 100 knots for precision approach to runway 09.

10:26 Cherokee 18, you are on downwind for Agana airport, complete landing checklist.

11:28 Cherokee 18, this is your final controller, turn right to 350, make all turns standard, descend to 3500 feet, landing check should be complete.

12:20 Cherokee 18, if lost comms within the pattern proceed to the missed approach point and continue with visual approach to 09.

12:45 Cherokee 18, continue right turn to 010, altitude should be 3500 feet.

13:14 Cherokee 18, turn right to 090.

14:00 Cherokee 18, you're coming up on final, commence 500 feet per minute descent.

15:05 Cherokee 18, you're on final, do not acknowledge any further transmissions, turn right to 095, altitude should be 3000 feet.

15:55 Cherokee 18, turn left 091, altitude should be 2500.

16:15 Cherokee 18, turn left 085, picking up a right drift.

16:57 Cherokee 18, should be coming up on 2000 feet, missed approach altitude is 1500 feet, at that point commence missed approach. Turn right 090.

17:25 Cherokee 18, check landing light on, continue descent heading 090.

17:53 Cherokee 18, coming up on missed approach, commence with missed approach instructions, climb out heading 110, climb out to 4000 feet, await further instructions.

19:10 Cherokee 18, turn right 130, continue climb to 4000 feet.

19:30 Cessna 20, turn left 230, maintain 3000 feet.

19:45 Cherokee 18, when level at 4000 feet, turn left 360.

20:50 Cherokee 18, if you desire further approaches, sqwawk 5555.

21:20 Cherokee 18, altitude should be 4000 feet, heading 360, increase speed to 120.

21:40 PSA 91, you're cleared to switch frequencies. Good day, sir.

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