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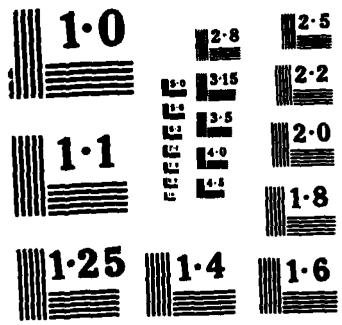

NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

Technical Memorandum 17-85

A COMPARISON OF VOICE AND KEYBOARD DATA ENTRY FOR A HELICOPTER NAVIGATION TASK

Frank J. Malkin
Kathleen A. Christ

December 1985
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Aberdeen Proving Ground, Maryland

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automatic speech recognition; human factors; pilot workload; data entry; keyboards; controls and displays; navigation; helicopter; aviation

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The Doppler navigation set, AN/ASN 128 was used to compare manual keyboard data entry of navigation map coordinates with an isolated-word speech recognition system. Twelve male Army aviators entered data by keyboard and by voice while controlling a helicopter flight simulator. The results indicated that although the keyboard mode was faster than the voice mode of data entry, the aviators preferred using voice. Voice data entry was perceived as requiring less effort and reducing pilot workload.

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However, the relative slowness and low accuracy (85.5 percent) of voice data entry highlight the limitations that may exist for speech recognition systems in performing time or task critical functions. Keywords:

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A COMPARISON OF VOICE AND KEYBOARD DATA ENTRY FOR A HELICOPTER NAVIGATION TASK

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CONTENTS

A COMPARISON OF VOICE AND KEYBOARD DATA ENTRY FOR A HELICOPTER NAVIGATION TASK

INTRODUCTION

The high visual and manual workload that Army helicopter pilots experience necessitates developing and refining new technologies which may be put to use in the cockpit. One advanced technology which has potential for reducing pilot workload is voice recognition. Having the ability to enter data by voice, rather than by keyboard frees the pilot to keep both hands on the flight controls.

The navigation task is being investigated for the possible application of voice technology. For this study, the Doppler navigation set keyboard was used to compare manual data entry of map coordinates[1] to voice data entry of map coordinates while controlling a helicopter simulator. The Doppler system is currently used in Army helicopters. It provides worldwide navigation data in either latitude/longitude or universal transverse mercator (UTM) coordinates.

Several studies have been performed evaluating voice data entry and manual data entry (Aretz, 1983; Jay, 1981; Ruess, 1982; Skriver, 1979; Wyatt, 1983). Voice and manual data entry were compared in each study for time to input, accuracy of input, and performance of a simultaneous task. In the Aretz study, subjects were required to fly a fighter cockpit simulator while performing the data entry task. Subjects in the Skriver study performed a one-dimensional tracking task while entering data manually and vocally. Similar tasks were performed for the other studies referenced above.

Results of these studies have led to essentially the same conclusions. When entering data points is the only task, manual entry is faster than voice entry. However, voice is more effective for complex data entry tasks where long strings of digits and alphanumerics are combined. Voice entry was also shown to be less disruptive to the tracking and flight tasks than manual entry. Subjects were better able to maintain their altitude and airspeed while flying and maintain position of the cursor while tracking when data entry was performed by voice.

When these results are related to actual flight, it would indicate that voice data entry would reduce pilot workload during low-level flight and other difficult missions. By using voice data entry, the pilot can keep his hands on the controls and make the necessary inputs to maintain the required flight parameters. This will be especially important in future single-place helicopters, the concepts for which are now being formulated by the Army.

[1]Coordinates provide a reference between points on the earth's surface and their location on a map.

OBJECTIVE

The objective of this study was to compare data entry using a currently available speech recognition system and a current military navigation set keyboard when: (1) the entry of UTM coordinates was the sole task performed, (2) the entry of UTM coordinates was performed concurrently with controlling a helicopter simulator during level flight, and (3) data was entered during terrain-following flight. The differences between the two modes of entry for data entry time, response time, and data input errors were evaluated along with the flight performance data to determine which was more effective.

METHODOLOGY

Participants

Twelve male Army aviators assigned to the U.S. Army Aberdeen Proving Ground Installation Support Activity, Aberdeen Proving Ground, Maryland, participated as subjects in this study. The subjects had an average of 2,346 flight hours in helicopters and were currently averaging 32 hours of flying time per month. One subject had limited experience using a voice recognition device, while three subjects had limited experience operating the Doppler navigation set.

Apparatus

The following apparatus was used in this study:

(1) General Aviation Trainer (GAT) II helicopter simulator
(2) Interstate Electronics VRT 103 voice recognizer with one Shure Brothers microphone
(3) Doppler navigation set, AN/ASN 128
(4) Two video cameras with time clocks and tape recorder
(5) VAX 11/780 computer and terminal
(6) PDP 11-34 computer and terminal
(7) Vector General stroke writer

Procedure

Each subject was individually trained and tested. The training and testing of one data entry method were completed before proceeding to the next. The presentation order of the manual and voice data entry methods, as well as flight control tasks, was counterbalanced. The subjects all received a briefing on the purpose of the study and the procedures to be followed.

Training

Upon completion of the procedural briefing, the subject received instructions on how to operate the GAT II helicopter simulator. Training flights were provided for the level flight task and for the terrain-following flight task. The terrain-following flight task was especially demanding visually and manually because a given altitude had to be maintained above ground elevation when the ground elevation was constantly changing. The forcing function used to create the terrain flight was formed by adding together three nonharmonic sine waves. The flight display is shown in Figure 1.

The subject was instructed to maintain the specified flight parameters: airspeed, 90 knots; heading, 270°; and altitude, 500 feet above ground level. Proficiency for the level-flight task was attained when airspeed was held within 10 knots, altitude within 50 feet, and heading within 5° for at least 30 seconds. The subject was considered proficient at terrain flight when the flight parameters were held within 15 knots, 10°, and 150 feet for at least 30 seconds. All subjects received a minimum of 10 minutes each of level and terrain flight training. Subjects who were not proficient after 20 minutes were to be excused. All subjects were able to meet these criteria.

Before manual data entry was to be tested, the subject was given instructions on how to enter waypoint coordinates (navigation points) in UTM format on the Doppler keyboard. Twelve destination coordinates may be entered into this system: 0-9, Present Position, and Home. Spheroid, variation, and zone data can also be entered for each destination. In this study, only destination coordinates were entered. In UTM format, the waypoint coordinate consists of two alpha characters and eight digits (e.g., AB12345678). A list of the coordinates used is included in Appendix A. These coordinates were selected from a military map of the Fulda Gap area of Germany.

To enter data manually into the Doppler system, the subject first had to turn a thumbwheel to the waypoint position to be entered. Because of the internal mechanics of the system, the subject then had to depress the KEYBOARD key three times before the coordinate could be entered. Alpha characters require two key depresses, while the digit entries require one keystroke. Upon completion of the data entry, the ENTER key was depressed to enter the coordinates into the system. The keyboard is illustrated in Figure 2, and its location in the cockpit relative to the flight controls is shown in Figure 3.

To correct input errors on the keyboard, the CLEAR key was used. When depressed once, the last character entered was erased. When depressed twice, all characters entered up to that point were erased. The subject could then reenter the correct UTM coordinates. All subjects were given practice correcting input errors.

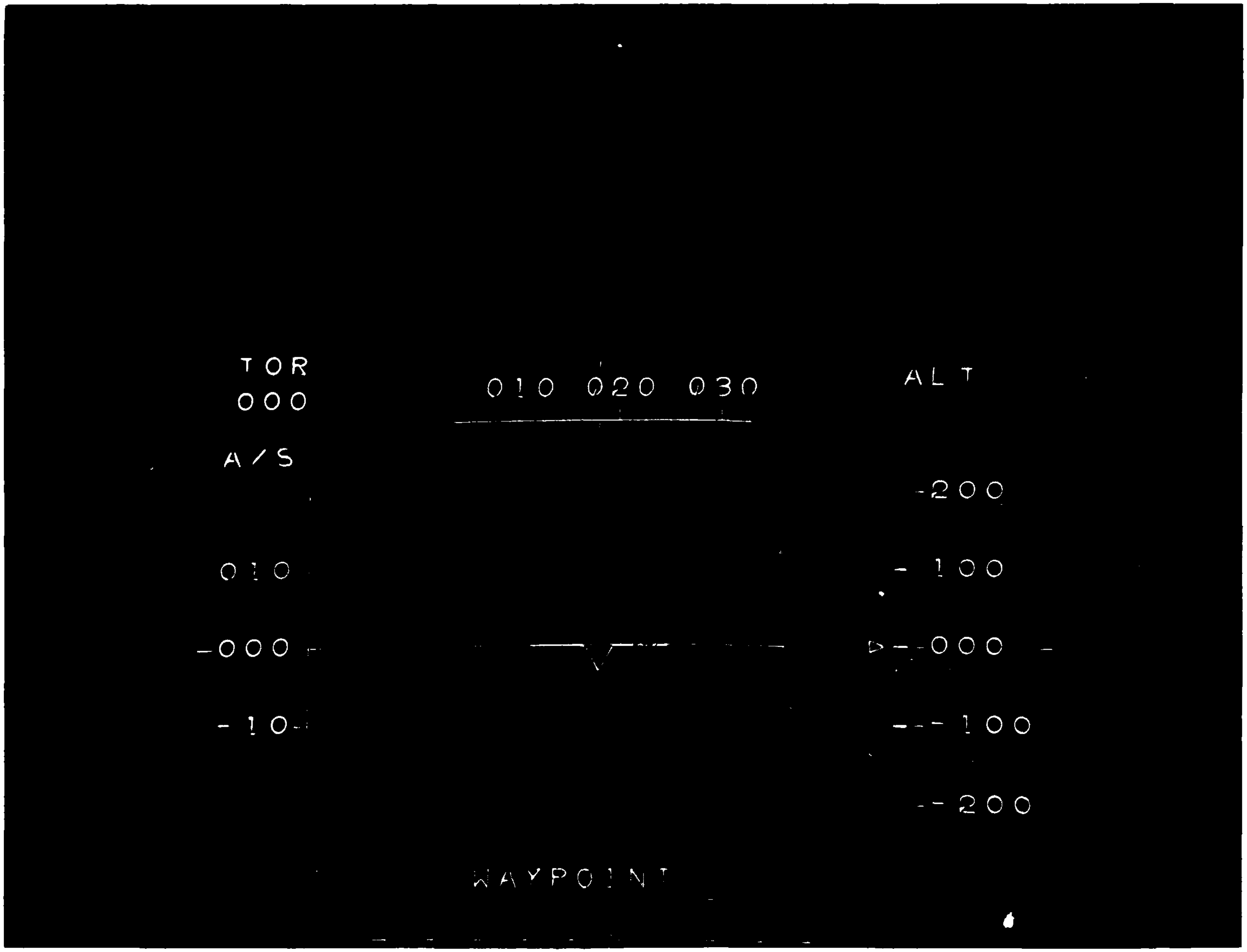

Figure 1. Flight display.

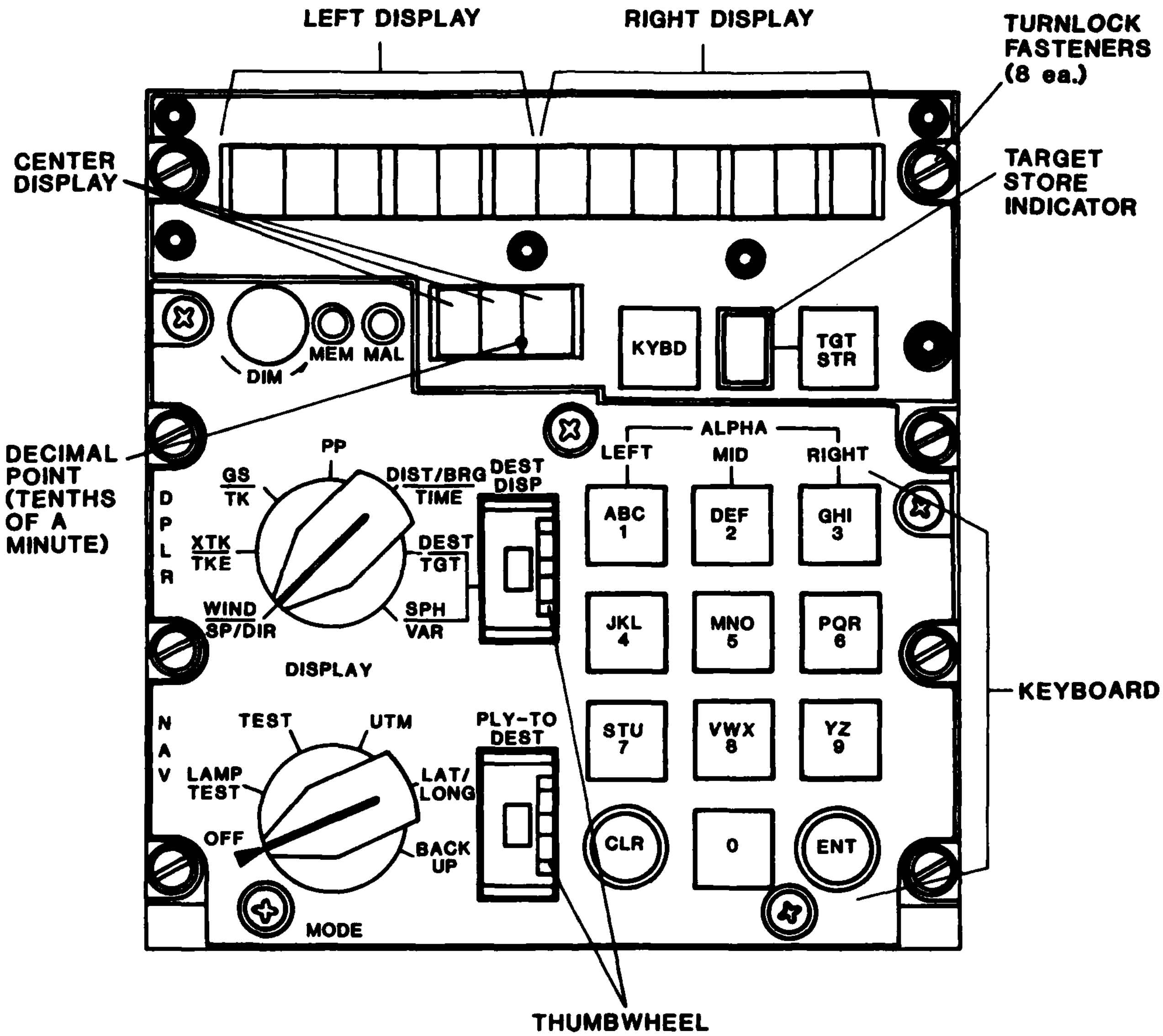

Figure 2. Doppler navigation set.

Figure 3. Cockpit layout.

A minimum of 10 waypoint coordinates was provided for the subject to practice entering data on the keyboard. Proficiency at the keyboard was attained when 5 consecutive waypoints were entered correctly. If proficiency was not attained after 25 practice waypoints had been entered, the subject was to be excused. All subjects were also able to meet this criterion.

After completing the training for the simulator and for the keyboard, the subject was given level and terrain-following flight tasks to practice entering waypoints while flying the simulator. The subject was given the opportunity to enter four waypoints during each flight task to ensure that the testing procedures were understood.

For voice data entry, each subject first had to provide the voice recognizer with a sample of his speech for each utterance used during data entry. The vocabulary for this study consisted of 18 words (see Appendix B). Five training passes were used to form the voice templates for each individual. The subjects were instructed to talk naturally and consistently from one training pass to another.

After the subjects trained the recognizer, they became familiar with voice data entry procedures and practiced entering data for at least 10 waypoints. Because the recognizer used was an isolated-word system, the subjects were instructed to wait until the character entered was displayed before attempting to input the next digit or alpha character. The characters were displayed at the bottom of the flight display (see Figure 1).

The subjects could correct errors in two ways. The word CLEAR removed from the display all characters entered for the current waypoint. When either the command DELETE or CORRECTION was given, the last character entered would be deleted from the display. Each time the command was repeated, the last character displayed would be deleted. Each subject was given practice using these correction techniques.

After the waypoint coordinate was entered, the OUT command was to be given to enter the waypoint coordinate. The coordinate would be removed from the display, and the waypoint to be entered next would be indicated.

The same criterion for proficiency that was used for manual data entry was also used for voice data entry. One subject had to be dismissed from the study for failure to meet this criterion. To keep the sample size at 12, another aviator was trained, met the criterion, and was tested. After four separate training sessions of the complete vocabulary, followed each time by additional training of individual words, the system failed to accept two consecutive waypoint coordinates. Although the subject had prior experience with a voice recognition system; he was inconsistent in his speech and did not articulate his words.

The subjects were provided with training flights for both level and terrain following to practice entering coordinates by voice while flying the simulator. As with manual data entry, the subjects were given the opportunity to enter four waypoints for each task condition.

Testing

Actual testing occurred upon completion of the training for each mode of data entry. Two video cameras were mounted inside the simulator to provide the researchers with a view of the keyboard and of the flight display. The 10 waypoint coordinates to be entered were located on a kneeboard attached to the subject's leg. A different set of waypoint coordinates was provided for each of the task conditions.

When data entry was the sole task to be performed, the subject was seated in the simulator with a kneeboard containing 10 coordinates. The subject was then prompted over headphones when to enter each coordinate (ENTER WAYPOINT 1). The instructions given to the subject were to enter the waypoint coordinates as quickly and accurately as possible. The speed of data entry was taken from the videotape after the test sessions.

When data entry was performed along with the flight tasks, the subject was told to perform these tasks as he would in an operational setting. At the start of the test session, the subject was allowed sufficient time to stabilize the simulator within the parameters stated earlier. When the simulator was stabilized, the subject was then instructed, through the headset, to enter the first waypoint. After data entry was completed, the subject was given time to stabilize the simulator again. The same amount of time it took to enter the waypoint was allotted to the sole task of flying the simulator after it was stabilized. The subject was then instructed, over the headphones, to enter waypoint 2. The process was repeated until all 10 waypoints were entered. The same procedure was used for both manual and voice data entry.

Data Collection

During the test session, the computer sampled the heading, airspeed, and altitude eight times per second. The eight samples were then averaged and recorded once each second. Flight performance was measured as the root mean square (RMS) error of the heading, airspeed, and altitude during the entry of waypoint coordinates and when the flight task was the sole task performed. The RMS errors of each condition were then compared.

Data entry time was taken from the videotape of the testing sessions for the manual method. Data entry time for the voice method was recorded by the computer. For the manual method, data entry time was measured as the time to input only the two alpha and eight numeric characters which make up the waypoint coordinate and to depress the ENTER key. When entered without any errors, 13 keystrokes were required. Data entry time for the voice method was measured as the time from the first utterance (the first alpha character) to the last utterance (the word OUT). When entered without any errors, 11 utterances were required.

Response time was also taken from the videotapes. This time refers to the time when the prompt was given to enter the waypoint coordinate to when the subject began to enter the data. For the manual mode, the additional time needed to enter the required keystrokes before actual data entry could be accomplished was included. The response time was added to the data entry time to compute the total data entry and response time.

Accuracy of data entry referred to the actual keystrokes or utterances beyond the minimum required. For the voice method, this number included misrecognitions (voice recognizer system confused the word entered with another) and nonrecognitions (voice recognizer system did not recognize the utterance). The computer recorded the misrecognitions. Nonrecognitions were collected from the videotapes of the test sessions.

After completion of the testing, subjects completed a questionnaire regarding their preferences of manual or voice data entry for each task condition. A structured verbal debriefing for each subject was also conducted at the end of testing. The questionnaire is included in Appendix C.

Experimental Design

A 2x3x12 factorial design with repeated measures was used. All subjects were tested with both data entry methods in all task conditions. The presentation order of the manual and voice data entry methods, as well as flight control tasks, was counterbalanced. The independent variables were data entry mode (voice, keyboard), task condition (no flight, level flight, terrain-following flight), and subjects. The dependent variables were speed of data entry, response time, accuracy, and flight performance.

RESULTS

Objective Data

For each of the combinations of independent variables, data for 10 waypoint entries were obtained. In initial exploratory univariate analyses of variance, all waypoint data were placed as factors in the analysis models. There were no significant main effects or interactions involving this trial effect, and in subsequent analyses, it was removed from the models.

A univariate analysis of variance was performed for each of the dependent measures using the SAS Institute data analysis software package (SAS Institute Inc., 1982). Since the design had repeated measures on subjects, the procedure described by Horton (1978) for adjusting the degrees of freedom for significant effects was followed to correct for violations of covariance assumptions. Tests for significance of interactions between data entry mode and flight task were made.

The means and standard deviations for the data entry and flight task performance measures and the summary analysis tables for these measures are provided in Appendix D. During the study, problems were encountered in recovering some of the data. The degrees of freedom for missing subjects were adjusted accordingly.

In the following paragraphs, the results of the significant F tests for each of the measures are summarized.

Data Entry

Data Entry Time. Keyboard data entry was significantly faster than voice data entry; $F(1,8)=18.38$, $p<.0027$. There was also a significant effect for flight task condition; $F(2,16)=7.72$, $p<.05$. Data entry during the no-flight task was faster than data entry during the terrain-following flight task. There were no significant interactions (see Tables 1D and 2D and Figure 4).

Response Time. There was a significant interaction between the data entry mode and the flight task condition; $F(2,16)=7.29$, $p<.05$. Simple effects testing and a subsequent Bonferroni T test indicated that the response time when using the keyboard was significantly faster during the no-flight task than during the terrain-following flight task. The response time when using voice was also significantly faster during the no-flight task than during the terrain-following flight task. The response time for voice was faster than for keyboard in the no-flight, level flight, and terrain-following flight task conditions (see Tables 3D and 4D and Figure 5).

Total Data Entry and Response Time. There was a significant interaction between the data entry mode and the flight task condition; $F(2,14)=5.56$, $p>.05$. Simple effects testing followed by a Bonferroni T test indicated that the total data entry and response time for the keyboard was significantly faster during the no-flight task than during the terrain-following flight task. Keyboard was faster than voice for the no-flight

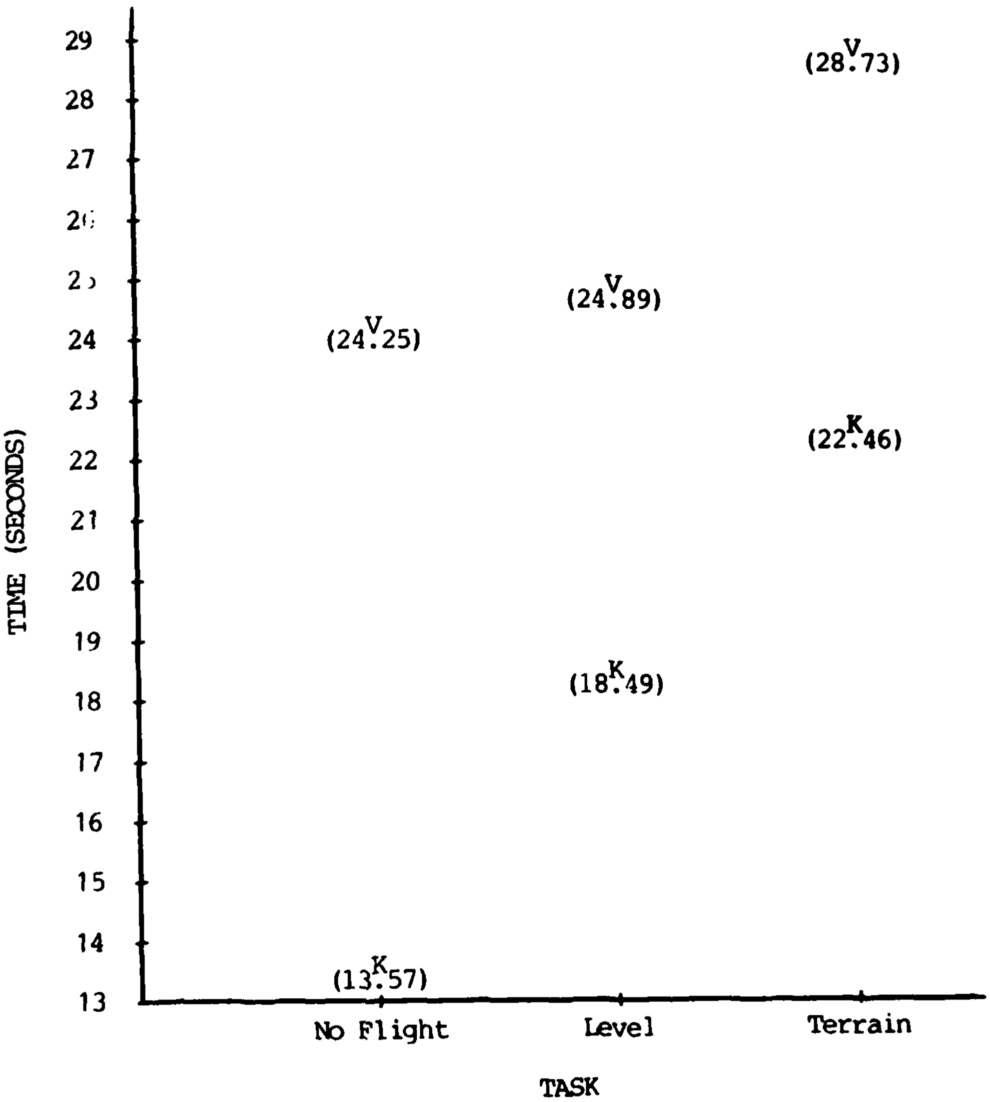

Figure 4. Data entry time.

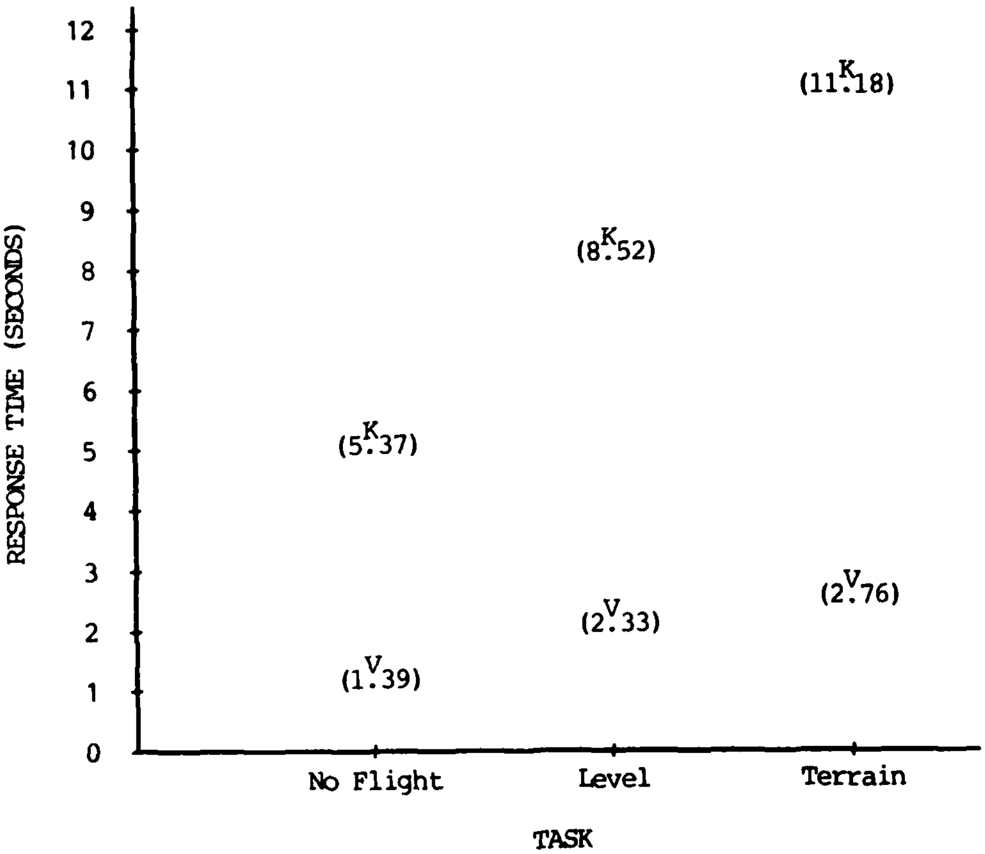

Figure 5. Response time.

task, but there was no significant difference between keyboard and voice for level flight or terrain-following flight (see Tables 5D and 6D and Figure 6).

Errors. There were significantly more voice utterances than keystrokes; $F(1,8)=22.50$, $p<.001$. This difference is attributed to the number of utterances that had to be repeated until recognized by the speech recognition device (see Tables 7D and 8D and Figure 7).

Flight Performance

Heading. There were no significant interactions or effects for heacing control (see Tables 9D and 10D).

Airspeed. Airspeed control was significantly better during level flight than it was during terrain-following flight; $F(1,6)=8.03$, $p<.0298$ (see Tables 11D and 12D).

Altitude. Performance data for altitude control during terrain-following flight could not be recovered.

Subjective Data

The subjects overwhelmingly preferred the voice data entry over the keyboard. The results are summarized in Table 1.

DISCUSSION

Obviously, these results are influenced by the design features and limitations of the specific speech recognizer and keyboard used in this study. Data entry time using the isolated-word speech recognizer was slowed considerably by waiting for feedback (each character appearing on the video display) before saying the next character. The time to enter data by voice was also affected by the number of utterances that had to be repeated several times until recognized by the speech recognizer. Response time for the keyboard was affected by the design feature which required that the KEYBOARD key be activated three times in succession before entering data. This was an additional step not required with voice.

The greater number of errors when using voice is attributed to the number of utterances that were not recognized by the speech recognizer. There was no significant difference between voice and keyboard in the number of human input errors. The overall recognition accuracy of the speech recognizer for this study was 85.5 percent.

As indicated in Figures 4, 5, and 6, the corresponding increase in data entry and response time with flight task difficulty is not as

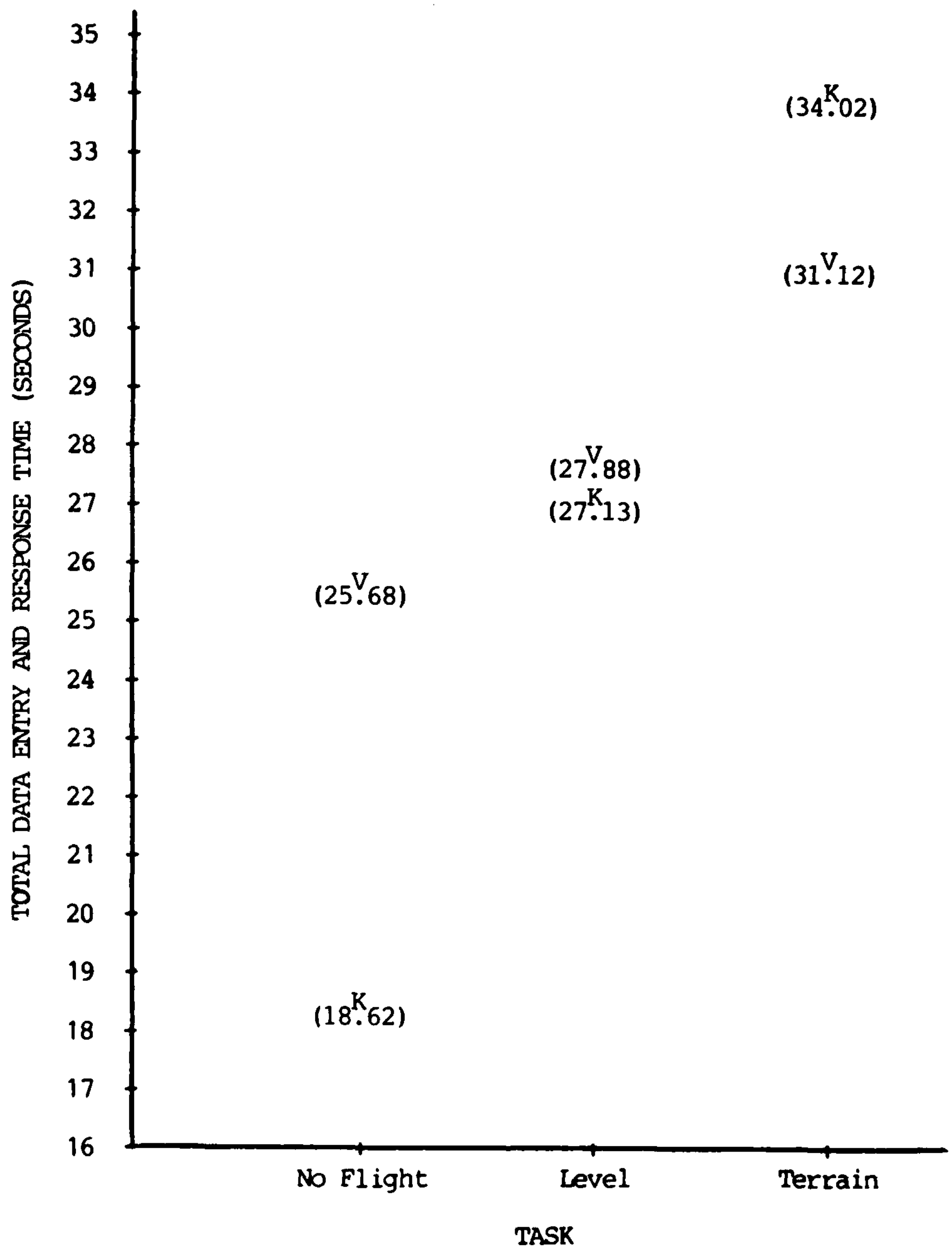

Figure 6. Total data entry and response time.

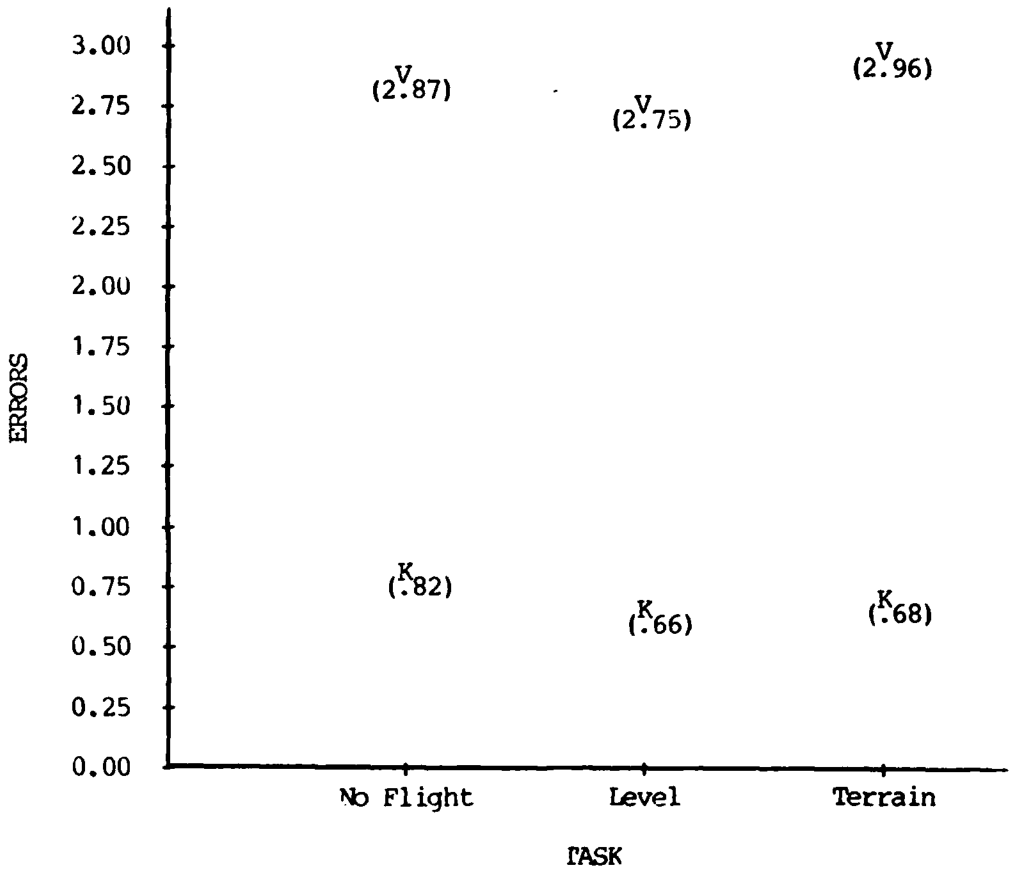

Figure 7. Mean errors.

TABLE 1

Data Entry Preferences

Manual Much Better	Manual Slightly Better	Equal	Speech Slightly Better	Speech Much Better
				S1 - NF, LF, TF
				S2 - NF, LF, TF
			S3 - NF	S3 - LF, TF
			S4 - NF, LF	S4 - TF
			S5 - NF, LF	S5 - TF
			S6 - NF, LF	S6 - TF
S7 - NF			S7 - LF	S7 - TF
				S8 - NF, LF, TF
			S9 - NF, LF	S9 - TF
S10 - LF, TF	S10 - NF			
	S11 - NF	S11 - LF	S11 - TF	
			S12 - NF, LF	S12 - TF

Note. LF - level flight
NF - no flight
TF - terrain flight
S - subject

dramatic for voice as it is for keyboard. This is an indication that there is possibly a greater time-sharing conflict between keyboard data entry and the flight task than there is between voice data entry and the flight task. In fact, both hands are required to control a helicopter; and the left hand that was used for the keyboard could not be removed from the collective lever for very long, especially during the terrain-following flight task.

Flight performance was not disrupted by either method of data entry. A plausible explanation for this is that the subject pilots were instructed to prioritize conflicting attention demands as they would in an operational aircraft. Observation of the videotapes indicates that the pilots concentrated on flight performance and entered data as flight-path control permitted. Thus, flight performance was not disrupted by data entry but data entry and response times became longer as the flight task became more complex.

CONCLUSIONS

The objective of this research was to compare the relative merits of keyboard and voice for entering navigation data during helicopter flight operations. One may theorize that, although it took longer for the actual entry of data using voice, voice required less effort. The workload of the pilot entering data while maintaining flight control is greater with keyboard than it is with voice. This theory is supported by observing the cockpit videotapes and by the results of the subjective ratings.

The subjective data indicate that the majority of aviators who participated in this study perceived voice data entry as a workload reducer and preferred it to the Doppler keyboard. However, if voice is to be used for time or task critical functions, both speed and accuracy must be improved. These results highlight the limitations of isolated-word speech recognition devices when entering digit strings. It appears that a connected-word speech recognition capability which permits consecutive utterances without pauses may reduce data entry time. But, as with isolated-word speech recognition, effective response feedback procedures will be important.

A future study is planned using a connected-word speech recognizer to determine if speed of voice data entry can be significantly improved.

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APPENDIX A

UNIVERSAL TRANSVERSE MERCATOR (UTM) COORDINATES

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DATA ENTRY SOLE TASK

1. MB 8479 3615
2. NA 1487 9877
3. NB 4173 1976
4. NB 6087 4045
5. NB 8502 2498
6. NB 7312 1346
7. NA 6155 9166
8. NA 2143 9335
9. MB 8591 2297
10. MA 9886 8664

DATA ENTRY DURING LEVEL FLIGHT

1. MB 8490 3227
2. MB 7882 2905
3. MA 8450 9011
4. NB 2037 0294
5. NB 3509 0738
6. NB 5258 3877
7. NB 7348 4430
8. NA 7169 9492
9. NA 4867 9529
10. NB 9235 3107

DATA ENTRY DURING TERRAIN-FOLLOWING FLIGHT

1. NA 2750 9475
2. NA 6634 9005
3. NB 8219 2130
4. NB 9166 3910
5. NB 4345 2728
6. MB 8210 2503
7. MB 8445 1223
8. NB 4402 3345
9. NA 3334 9431
10. NB 7633 0307

UTM COORDINATES USED DURING PRACTICE

1. MB 8566 1689
2. MB 8459 9741
3. NA 0355 8947
4. NA 2554 9879
5. NB 4193 1234
6. NB 6840 4201
7. NA 5246 9704
8. NB 7326 9888
9. NB 7970 1628
10. MB 8329 7631
11. NA 4078 9517
12. NA 5813 9788
13. NB 7394 0770
14. NB 8843 2811
15. MB 8756 0673
16. NA 0883 8985
17. NB 3152 0135
18. NB 4744 3727
19. NB 8142 4693
20. NB 8662 4225

APPENDIX B

VOCABULARY LIST

VOCABULARY LIST

1. Correction
2. Clear
3. Out
4. Delete
5. Zero
6. One
7. Two
8. Three
9. Four
10. Five
11. Six
12. Seven
13. Eight
14. Nine
15. Alpha
16. Bravo
17. Mike
18. November

APPENDIX C

RATING SCALES

RATING SCALES

The following rating scales were used to determine subject preferences:

a. Compare the manual and speech methods of entering waypoint coordinates when data entry is the sole task performed. Circle the appropriate X.

MANUAL MUCH BETTER THAN SPEECH	MANUAL SLIGHTLY BETTER THAN SPEECH	EQUAL	SPEECH SLIGHTLY BETTER THAN MANUAL	SPEECH MUCH BETTER THAN MANUAL
X	X	X	X	X

b. Compare the manual and speech methods of entering waypoint coordinates when data entry is performed during level flight. Circle the appropriate X.

MANUAL MUCH BETTER THAN SPEECH	MANUAL SLIGHTLY BETTER THAN SPEECH	EQUAL	SPEECH SLIGHTLY BETTER THAN MANUAL	SPEECH MUCH BETTER THAN MANUAL
X	X	X	X	X

c. Compare the manual and speech methods of entering waypoint coordinates when data entry is performed during terrain-following flight. Circle the appropriate X.

MANUAL MUCH BETTER THAN SPEECH	MANUAL SLIGHTLY BETTER THAN SPEECH	EQUAL	SPEECH SLIGHTLY BETTER THAN MANUAL	SPEECH MUCH BETTER THAN MANUAL
X	X	X	X	X

APPENDIX D

STATISTICAL TABLES

TABLE 1D

Data Entry Time (seconds)

Entry	Task	Mean	SD
Keyboard	No Flight	13.57	6.82
	Level	18.49	7.01
	Terrain	22.46	9.82
Voice	No Flight	24.25	11.87
	Level	24.89	11.24
	Terrain	28.73	13.10

TABLE 2D

Data Entry Time
Analysis of Variance Summary Table

Source	SS	df	F
Subjects (S)	5,142.72	8	8.20
Entry (E)	9,263.48	1	18.38*
E x S	4,032.45	8	
Task (T)	3,461.76	2	7.72**
T x S	3,586.97	16	
E x T	463.99	2	4.00***
E x T x S	928.55	16	

*$p < .0027$
**The calculated F exceeded the criterion F with the most conservative adjustment for degrees of freedom. $p < .05$
***The calculated F did not exceed the criterion F with the most conservative adjustment for degrees of freedom.

TABLE 3D

Response Time (seconds)

Entry	Task	Mean	SD
Keyboard	No Flight	5.37	3.28
	Level	8.52	6.09
	Terrain	11.18	6.23
Voice	No Flight	1.39	0.52
	Level	2.33	1.61
	Terrain	2.75	2.30

TABLE 4D

Response Time
Analysis of Variance Summary Table

Source	SS	df	F
Subjects (S)	2,078.64	8	23.93
Entry (E)	5,354.25	1	47.31*
E x S	905.32	8	
Task (T)	1,166.40	2	13.44**
T x S	694.24	16	
E x T	440.77	2	7.29**
E x T x S	483.95	16	

*$p<.0001$
**The calculated F exceeded the criterion F with the most conservative adjustment for degrees of freedom. $p<.05$

TABLE 5D

Total Data Entry and Response Time (seconds)

Entry	Task	Mean	SD
Keyboard	No Flight	18.62	7.06
	Level	27.13	9.99
	Terrain	34.02	13.05
Voice	No Flight	25.68	11.79
	Level	27.88	12.26
	Terrain	31.11	13.80

TABLE 6D

Total Data Entry and Response Time
Analysis of Variance Summary Table

Source	SS	df	F
Subjects (S)	10,541.65	7	.0001
Entry (E)	722.44	1	.86
E x S	5,858.87	7	
Task (T)	7,963.95	2	12.46*
T x S	4,473.34	14	
E x T	1,466.10	2	5.56*
E x T x S	1,844.30	14	

*The calculated F exceeded the criterion F with the most conservative adjustment for degrees of freedom. $p < .05$

TABLE 7D

Errors

Entry	Task	Mean	SD
Keyboard	No Flight	0.82	2.95
	Level	0.66	2.04
	Terrain	0.68	2.34
Voice	No Flight	2.87	3.81
	Level	2.75	4.67
	Terrain	2.96	4.02

TABLE 8D

Errors
Analysis of Variance Summary Table

Source	SS	df	F
Subjects (S)	191.27	8	2.21
Entry (E)	693.6	1	22.50*
E x S		8	
Task (T)	6.3	2	0.18
T x S	287.9	16	
E x T	0.6	2	0.03
E x T x S	136.9	16	

*$p < .001$

TABLE 9D

Heading (root mean square)

Entry	Task	Mean	SD
Keyboard	No Flight	----	----
	Level	1.80	3.00
	Terrain	2.17	2.06
Voice	No Flight	----	----
	Level	1.44	1.52
	Terrain	1.84	2.30

TABLE 10D

Heading
Analysis of Variance Summary Table

Source	SS	df	F
Subjects (S)	12.43	6	
Entry (E)	0.63	1	1.22
E x S	3.11	6	
Task (T)	1.39	2	5.07
T x S	1.65	6	
E x T	0.07	1	0.11
E x T x S	3.74	6	

TABLE 11D

Airspeed (root mean square)

Entry	Task	Mean	SD
Keyboard	No Flight	----	----
	Level	2.46	5.20
	Terrain	3.44	3.70
Voice	No Flight	----	----
	Level	2.04	1.84
	Terrain	3.47	2.51

TABLE 12D

Airspeed
Analysis of Variance Summary Table

Source	SS	df	F
Subjects (S)	552.26	6	6.90
Entry (E)	3.81	1	0.30
E x S	75.60	6	
Task (T)	86.99	1	8.03*
T x S	64.99	6	
E x T	7.62	1	1.06
E x T x S	43.06	6	

*$p < .0298$

END

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