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TRAINING TECHNOLOGY

MEASURING PILOT PROFICIENCY ON AN INSTRUMENT

TRAINING MANEUVER

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EDUCATIONAL TECHNOLOGY

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The record/playback feature of modern, advanced digital simulators indicates a potential for the achievement of important methodological advances in observer training and in predetermining measurement reliability. An exploratory study recently completed showed that the record/playback feature of the Advanced Simulator for Pilot Training (ASPT) could be successfully used to facilitate the development and validation of a recording form for an instrument flight training maneuver. In addition, this feature

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was successfully used to train instructor pilot observers to reliably record maneuver performances using the form. These results have important research implications, since they will allow a degree of control over recording objectivity and reliability not previously possible. Researchers can be freed from after-the-fact correlational reliability estimations. In addition, innovative recording formats can be safely and efficiently developed and refined before validation in flight.

ARIZONA STATE
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OFFICE OF RESEARCH GRANTS AND CONTRACTS

AFOSR-TR- 78 - 0211

October 1, 1976

Alfred R. Fregly, Ph.D.
Program Manager
Life Sciences Directorate
Air Force Office of Scientific Research
Department of the Air Force
BOLLING AIR FORCE BASE
Washington, D.C. 20332

Dear Dr. Fregly:

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AFOSR-76-2900

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Rule Learning and Systematic Instruction in
Undergraduate Pilot Training

Vernon S. Gerlach, Principal Investigator

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College of Education
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Tempe, Arizona

August, 1977

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Introduction

Objective measurement of pilot proficiency has long been a problem for researchers attempting to improve pilot screening and training methods. Automated performance measurement has been considered the only completely objective method. The approaches have run the gamut from film or video recording (Wood and Hagin, 1974) to instrumented aircraft (Knoop and Welde, 1973) and advanced simulators (Waag, 1975). Unfortunately, few of these efforts have resulted in readily available measurement systems or schema: film/video techniques are difficult to evaluate and score and instrumented aircraft and advanced simulators are expensive.

As a result, flying training research still relies heavily on subjective instructor and check-pilot grades. Although several training research studies carried out in recent years have used these kinds of subjective measures successfully (e.g., Reid, 1974), many problems arise for which more precise, objective data are required if meaningful discriminations are to be made.

The alternative to automated measurement--controlled human observation and recording using standardized and structured methods and materials--has provided useful data when the recording instrument has been properly designed and the observer-recorder carefully trained in its use (Ericksen, 1952). While several investigators have used trained observers successfully (e.g., Prophet and Jolley, 1969; Koonce, 1974), many others have avoided the technique because of the effort and time required to develop an effective recording form and to train observers to an acceptable level of recording reliability. Indeed, frequently the aircraft and instructor time needed were not available.

Clearly, observer recording as a pilot proficiency measurement tool would become more attractive if techniques were found to reduce the development time

and effort usually required. This report documents the development of an observer-recording form for the instrument training maneuver Vertical S-A in which the unique record/playback features of the Advanced Simulator for Pilot Training (ASPT) were used to increase the efficiency of format construction, reliability assessment, and observer training. Implications of this work for a revitalized interest in observer recording techniques as low cost objective measures of pilot skill are discussed.

Method

Maneuver Selection and Analysis

The Vertical S-A was selected as representative of the many instrument training exercises used to teach some of the skills required for actual weather flying. The student first establishes straight and level flight at a prescribed altitude and airspeed. Then he makes a transition to a constant rate climb of 1000 ft/min. After climbing exactly 1000 ft, he makes a transition to a 1000 ft/min. descent, descends 1000 ft, and concludes the maneuver by leveling off at his starting altitude.

Brecke, Gerlach, and Schmid (1976) showed that the maneuver may be envisioned as a series of steady states (straight and level, climb, etc.), separated by a series of transitions from one steady state to the next. Their maneuver segmentation provided a convenient set of discrete piloting behavior elements during which an observer could be expected to observe and record deviations from the prescribed parameters. Figure 1 graphically illustrates the flight path of the Vertical S-A and the maneuver segments defined.
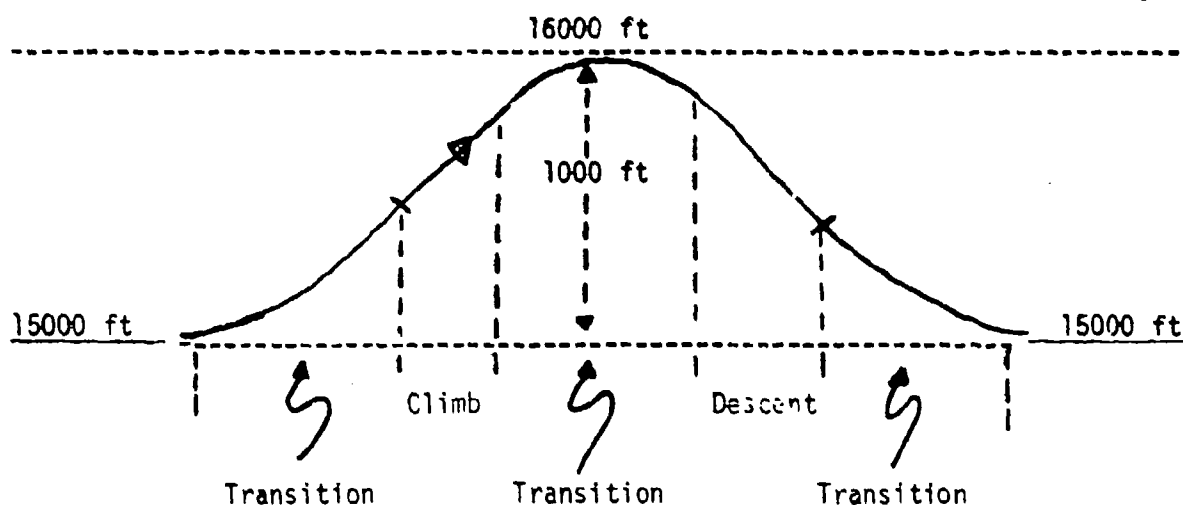
16000 ft

1000 ft

15000 ft

15000 ft

Climb

Descent

Transition

Transition

Transition

Figure 1. The Vertical S-A maneuver

Measurement Strategy

A number of decisions had to be made at the outset concerning the types of measures to be used and the role of the observer-recorder during in-flight data gathering. The first decision was to collect data and establish performance scores by maneuver segments rather than by time sampling. This approach is consistent with a logical analysis of the maneuver. It eliminates some of the difficulties found in time sampling, e.g., at a given point in time different pilots could be at different points in the maneuver and the resulting values would not be comparable.

The second decision was to obtain maximum deviation scores (where appropriate), accumulated over the entire segment. This was done because pilot observer-recorders are more accustomed to observing deviations from prescribed parameters than they are with observing those obtained by time sampling. Although detail in measurement is lost through this approach, experience has

also shown that time sampling is difficult for pilots (Ericksen, 1947).

The third decision was to limit instructor pilots (IPs) to recording observed values only and not to make any segment or overall maneuver performance appraisals. This was done to avoid the possibility that the IPs' recording accuracy might be influenced by attention to other performance variable they might customarily use.

Recording Format Development

Performance measurement staff scientists of the Air Force Human Resources Laboratory/Flying Training and expert instructor pilots from Williams AFB, Arizona assisted us in tne development of a first draft of a maneuver recording booklet. It contained both instructions for time intervals or points at which to make observations and scales on which to record the deviations from normal as they occurred. In general, it followed the style of the manual developed by Koonce (1974).

The pages were constructed so that as each page was turned, the instructions were on the left and the recording scales on the right. Both instructions and their corresponding scales were serially numbered. The booklet fit an instructor pilot's knee clipboard. A brief tryout in the ASPT revealed several format and observer-workload problems that needed correction.

Following revision, the booklet (Appendix A) was given a rigorous evaluation in the ASPT. Three instructor pilots (IPs) were used: one, in the left seat of the simulator cockpit, flew the Vertical S-A maneuvers; the second sat in the right seat as an observer-recorder; the third was stationed at the ASPT console in front of the cockpit repeater instruments. As a series of maneuvers was flown, the experimenter noted the major difficulties encountered. It

quickly became apparent that the observers were having difficulty keeping up with the maneuver and were losing data. For example, having to write down an actual value was found to be more difficult than marking a scale. In addition, several of the instructions for recording were so confusing that they caused errors.

The revisions were made and the booklet was again tested in the ASPT. As before, three IPs were used (one from the first group plus two new ones). One flew the maneuvers while the other two--one in the cockpit and one at the operator console--did the recording. The IP at the controls was instructed to fly a total of twelve Vertical S-As representative of the range of performances expected from students. After six such maneuvers, the two observers changed places so that each observed the same number of maneuvers in the cockpit and at the console.

Observer-observer agreement, although improved, was still inadequate. The experimenter's observations were confirmed during debriefing: too much detailed recording behavior was required, so that the observers were missing data and falling behind. The following specific problems and concerns were noted:

(1) The attitude indicator was a source of difficulty. Not only was it hard to read, but the effort expended caused delay and error in reading other instruments. Since attitude information is reflected in the vertical velocity indicator readouts, it was decided not to record attitude indicator readings henceforth.

(2) Power settings were also troublesome. Since they were included on the form mainly as indices of segment transitions and not as performance indicators per se, they were dropped from the form

and replaced by a simple notation indicating whether or not the subject "led with power".

(3) The straight-and-level segment was also deleted, since IPs and the experimenter agreed that it would not provide much useful information for the planned training experiments.

(4) Maneuver execution time had been included as a potentially valuable diagnostic index (Shipley, 1976). However, the IPs and research staff were experiencing difficulty defining and judging when the maneuver began and ended. This problem was eliminated by re-defining the start as "time at which the altimeter passes through 15,200 ft at start of climb," and completion as "time at which the altimeter passes through 15,200 on descent." This provided an operational definition of maneuver time which was extremely simple and which resulted in almost no loss of meaningful information.

(5) Photo-reduction to fit the IP kneeboard was discontinued because the pilots expressed a preference for a larger format and heavier card stock.

The resulting booklet is shown in Appendix B.

Observer Training

The record-playback feature of the ASPT was used to establish base-line standard Vertical S-A maneuver performances. An IP flew a series of S-A maneuvers simulating the range of performances expected of students. Twelve such maneuvers representing poor, average, and good student performances were

recorded and stored on both computer disc and magnetic tape.[1]

Two experimenters used the recording booklets to evaluate the twelve maneuvers as they were played back. By playing each maneuver several times at both regular and half speed, and observing individual parameters carefully, a very close approximation to the true values was achieved. These values were accepted as the criteria for instructor/observer training.

The two instructor pilots who were to serve as observers in the planned experiment were trained as follows:

(1) The IP was given a copy of the performance measure to examine. Any questions he had concerning the form or use of the measure were answered before the formal training session began.

(2) The IP was first seated at the ASPT console, in front of the instrument panel. He was given a stop-watch, pen, and a set of booklets for recording performances.

(3) The twelve trials were randomized for order of presentation. While the first maneuver was being played back, the IP recorded the values in the booklet.

(4) When the playback of the maneuver was finished, the values recorded by the IP were checked against the true values previously obtained and verified.

(5) The maneuver was replayed for the IP to show him where he had encountered difficulty and to suggest ways to improve performances.

---

[1]It had been hoped that an objective evaluation of these performances could be obtained using the ASPT automated performance measurement system to provide the "true" maximum range deviation and maximum deviation scores for the various maneuver segment parameters of interest. However, the existing ASPT software did not permit both evaluation of real-time flight and maneuver recording, nor did it allow evaluation of a st̃d maneuver while being played back.

(6) This procedure continued until the IP was able to make recordings which correlated highly with the experimenter verified values and was able to make "complete" recordings (i.e., without missing values for any of the parameters).

(7) The IP was then given an opportunity to make a number of recordings from the co-pilot seat in the ASPT cockpit to be sure that he performed as well there as at the console.

After the two IPs had been initially trained, a few minor changes were made to simplify the materials and procedures. Since the IPs were now thoroughly familiar with the points at which measures were to be recorded, the textual and diagrammatic portions of the booklet seemed superfluous. The maneuver segment recording pages were photo-reduced so that all five segments would fit on one 8-1/2" x 11" page. This eliminated page-turning, which had been a minor nuisance during training. The performance measures were printed on a heavy card stock to provide a firm marking surface (Appendix C). The two IPs were given further tryout on this final version to assure that the format simplification had not changed recording reliability.

Administration

The performance recording form was then used to gather data on three groups of subjects, each of which had received a different instructional treatment for flying the Vertical S-A. All of the subjects had previously been trained in the T-4 instrument trainer on the fundamental techniques of aircraft pitch, bank, and power control, but had not yet received specific instruction in flying a Vertical S-A.

Each subject flew six trials in accordance with the following instructions from his IP-observer:

"I will start you out at 15000 ft, 160 knots on a heading of 180°. You will have a few minutes to warm up by flying straight and level and then I will ask you to perform a Vertical S-A. You then may start when you are ready. I will record how well you do on this form (showed recording instrument). When you finish each trial, I will give you time to stabilize straight and level on heading, altitude, and airspeed before telling you to start another trial. There will be six in all."

Scoring

Each maneuver segment provided either a maximum range of deviation (for heading, airspeed, and vertical velocity), or a single deviation score (for maximum altitude and maneuver time). Since pilot behavior is conventionally described in terms of such variables as heading, altitude, and airspeed control, it was decided to combine the segment values for each of these variables by averaging across segments to obtain trial scores. No attempt was made, however, to combine these separate values into a single value for the complete maneuver.

Results

Evidence of learning during the six trials was considered to be a necessary and sufficient indicator of measurement sensitivity. Tables 1 and 2 show the mean deviation ranges for heading and airspeed for the three treatment groups. The absolute values reflect fairly good performance, even on the early trials. Analyses of variance of these data indicate that improvement over trials was

Table 1

Mean Heading Deviation Ranges in Degrees

Group:				Trial			
	n	1	2	3	4	5	6
I	10	2.2	2.1	1.4	1./	1.5	1.1
II	10	3.0	2.6	1.0	1.7	1.7	2.2
III	10	3.0	2.2	1.7	2.1	1.4	1.7

Table 2

Mean Airspeed Deviation Ranges in Knots

Group:				Trial			
	n	1	2	3	4	5	6
I	10	4.4	3.6	3.1	2.9	2.4	2.6
II	10	4.6	2.5	2.3	2.6	2.2	2.4
III	10	5.4	4.3	4.0	3.3	2.5	2.4

Table 3

Mean Vertical Velocity Deviation Ranges in Feet

Group:				Trial			
	n	1	2	3	4	5	6
I	10	529	535	489	497	525	587
II	10	414	350	269	283	343	335
III	10	425	413	398	411	380	314

Table 4

Mean Time Maximum Deviation Score in Seconds

Group:				Trial			
	n	1	2	3	4	5	6
I	10	21.2	21.3	18.7	17.3	19.6	17.6
II	10	12.3	8.8	5.4	3.9	5.2	6.5
III	10	12.9	4.9	6.6	13.2	7.0	7.3

was significant: $F(5, 135) = 3.34$, $p < .01$ for heading and $F(5, 135) = 11.53$, $p < .01$ for airspeed.

Tables 3 and 4 are mean deviation ranges for vertical velocity control and maneuver times. Although inspection shows that Treatment Group 1 was not improving, analyses of variance of these data also revealed significant trials effects for Groups II and III: $F(5, 135) = 3.60$, $p < .05$ for time. This indicates that these measures, too, were reflecting improvement with practice. There was a significant treatment effect and interaction due to the failure of Group I to improve over trials: $F(10, 135) = 5.44$, $p < .01$. This effect is explained in Brecke et al. (1976).

Discussion and Conclusions

That trained observers can use a well-designed recording form as a means of objectifying pilot performance measurement and of providing data useful for training methods research has long been established. One more demonstration is of little significance. What is of importance, however, is the methodological advance in observer training and in pre-determining measurement reliability through the use of the record-playback feature of modern, advanced digital flight simulators. This makes it possible to train observers to a desired level of recording reliability in lieu of having to accept post hoc estimates, as has been the case with all earlier exploration of observer-recorded measures. When one knows precisely what the true value should be for parameters of high interest and is able to fly a given maneuver set over and over, it is possible to train each observer to the same level of recording accuracy-- a degree of control over recording objectivity and reliability not previously possible. As a result, researchers are no longer confined to after-the-fact correlational reliability estimations.

As in this study, the observer recording approach to objective pilot performance measurement has been most successful in instrument flight training where both the maneuver and criteria can be conveniently described in terms of instrument readings. The full spectrum visual/motion simulation capability of the ASPT allows extension into contact flying, including aerobatics and formation. Innovative recording formats can be safely and efficiently developed and refined before validation in flight, and potential measurement techniques can be tested against the criteria of IP observability, recordability, workload, and safety. This could be a critical step as IPs might accept as useful a technique learned first in the trainer and then used in the airplane, whereas they might reject it if they encountered if for the first time under the stresses of a training flight.

Such a program can provide a "family" of measuring instruments to support training methods, research, and hardware evaluations which require more precise data than existing subjective measures allow.

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Appendix A

The function of this booklet is to provide a record for student performance in flying the Vertical S-A maneuver. The booklet consists of a series of scales on which the performance is recorded. Shown below is an example of a typical scale:

AIRSPEED

$$(-) \;|\;|\;|\;|\;|\;|\;|\;|\;|\;|\;|\;|\;|\;|\;|\;|\; (+)\; \text{KIAS}$$

144 148 152 156 160 164 168 172 176
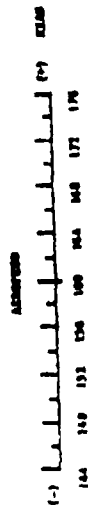
On this scale the I.P. records the Airspeed for one segment of the maneuver. The optimal airspeed (160 KIAS) is designated by a heavy line. The I.P. makes a mark(or marks) to indicate variations in the airspeed. If the student is performing at the optimal level, no mark is needed. If a variation from the optimal level goes off the scale, the I.P. writes in the approximate value of the deviation beside the scale.

For our purposes the Vertical S-A has been broken into six segments; Entry, Transition to Climb, Climb, Transition to Descent, Descent and Level-off. All the scales (except for heading) are constructed in absolute values, e.g. the Airspeed scale goes from 144 to 176 in 2 KIAS intervals. The heading scale goes from a zero point (in the center of the scale) and shows deviations in a positive direction (+4 thru +16) and in a negative direction (-4 thru -16). The heading assumed by a student will be considered the zero point and variations will be recorded from that heading.

VERTICAL S-A

Pilot Performance Record (UPT)

STRAIGHT & LEVEL

① ALTITUDE   FT.

② AIRSPEED   KIAS

③ HEADING   DEG.

TRANSITION TO CLIMB

④ PITCH   °

⑤ AIRSPEED   KIAS

⑥ HEADING   DEG.

⑦

LEVEL

The initial conditions for the maneuver are: Altitude—15000 Ft.,
Airspeed—180 KIAS, Heading—as assumed by the student.
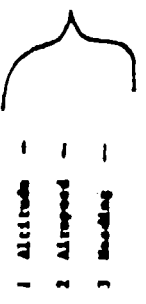
1 Altitude —
2 Airspeed —
3 Heading —

These three parameters should be measured
for the duration of the segment.
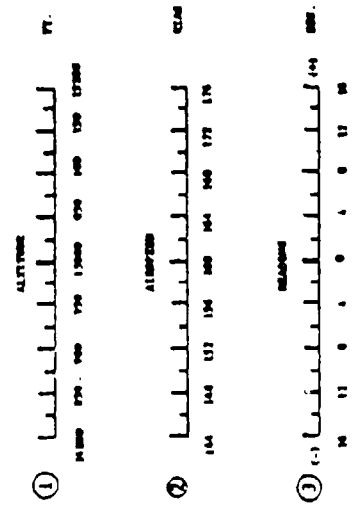
TRANSITION TO CLIMB

This segment starts when the student increases pitch and/or power.

4 Start time - Start the timer when the student increases the pitch
and/or the power.

5 Power - Make a mark to indicate the power setting
before increase. Then make marks to indicate variations around
the optimal RPM setting.

6 Airspeed -
7 Heading -

Measure for the duration of the segment.
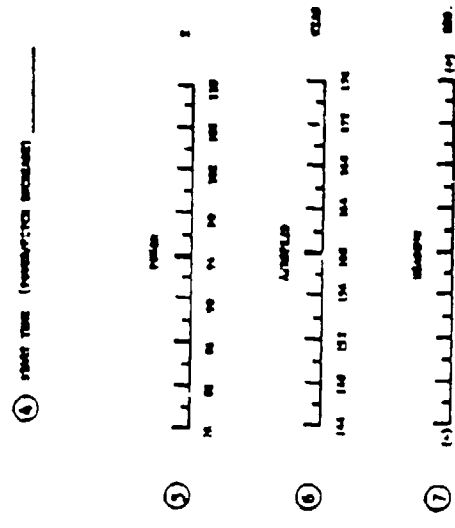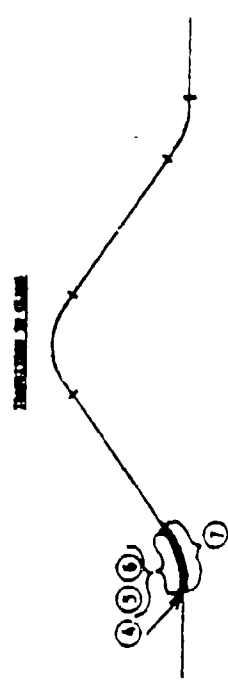
CLIMB

This segment starts after 200' of climb (approximately 13200').

8 VVI –

9 Airspeed – } Record throughout the segment

10 Heading –

11 Flight Indicator – The top of the "bubble" is used as the point for recording deviations.
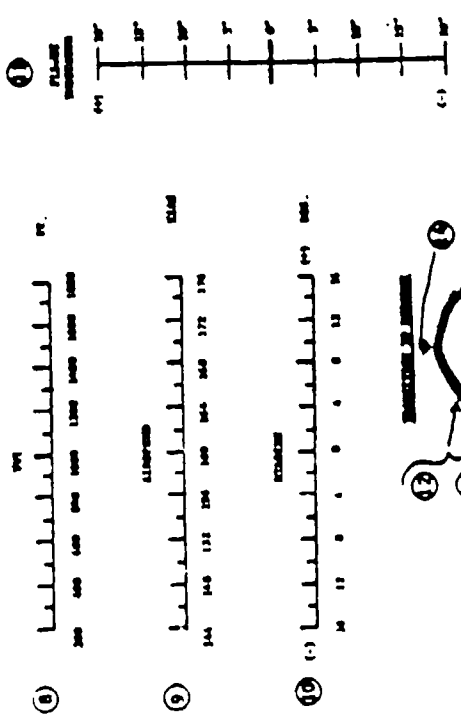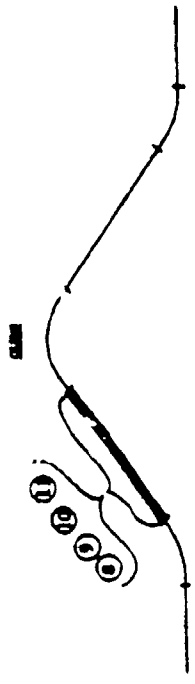
TRANSITION TO DESCENT

This segment starts when a significant power/pitch decrease is observed.

12 Lead Point – Note the altitude when power/pitch decrease.

13 Power/Pitch – Record the Tach(larnie)/smoothness for the segment.

14 Altitude – Write down the peak altitude reached.

15 Airspeed – } Record deviations for the whole segment.
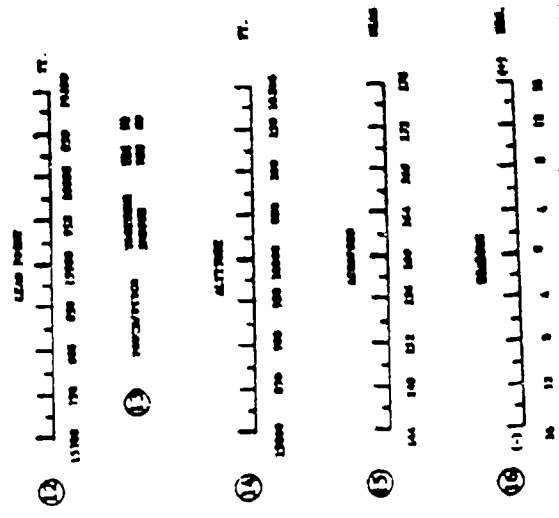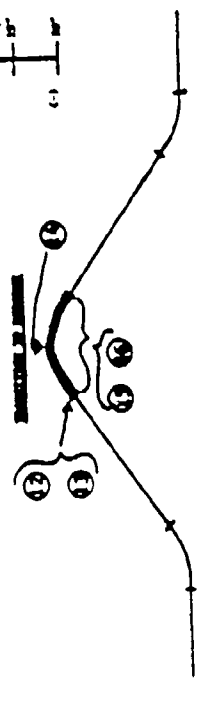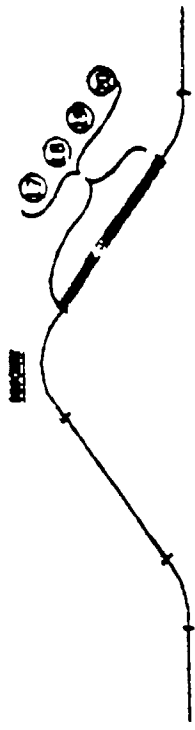
16 Heading –

19

DESCENT

This segment starts when the altitude reaches 15800'.

17 VVI –

18 Airspeed –   Record variations throughout the segment.

19 Heading –

20 Flight Indicator –   The bottom of the "bubble" is used as the point for recording deviations.
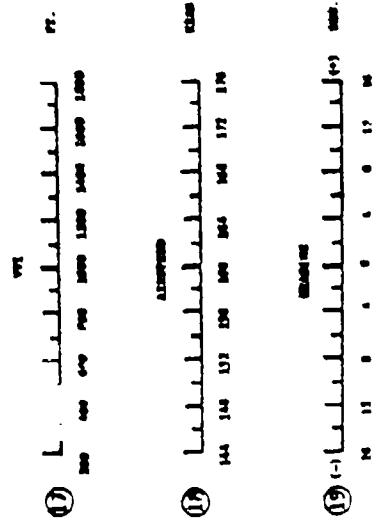
LEVEL-OFF

This segment starts when the altitude reaches 15100'.

21 Time at 15100' – Note the time (in seconds) the altitude is reached.

23 Increase Pitch/Power – Note the altitude significant pitch and/or power increases are observed.

22 Lead with Power – Circle Yes or No.

24 Power – Note the power setting at the start of the increase with a mark. Then note the variations around the optimal 82%.

25 Time at Pitch Steady – Stop the timer and record the total time when the pitch appears steady.
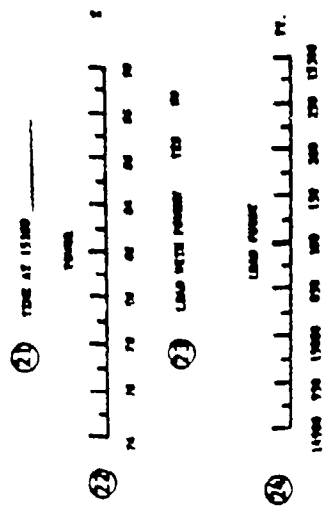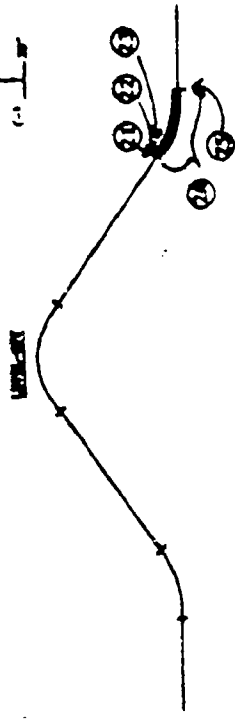
Appendix B

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of a series of scales on which the performance is recorded. Shown below
is an example of a typical scale:
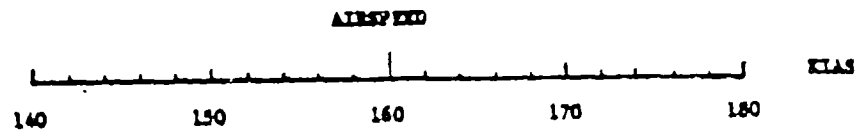
AIRSPEED

On this scale the I.P. records the Airspeed for one segment of the maneuver.
The optimal airspeed (160 KIAS) is designated by a heavy line. The I.P.
makes a mark (or marks) to indicate variations in the airspeed. If the student
is performing at the optimum level, no mark is needed. If a variation from
the optimal level goes off the scale, the I.P. puts a mark at the end of the
scale.

For our purposes the Vertical S-A has been broken into five segments:
Transition to Climb, Climb, Transition to Descent, Descent and Level-Off.
All the scales (except for Heading) are constructed in absolute values, e.g.
the Airspeed scale goes from 140 to 180 in 2 KIAS intervals. The heading
scale goes from a zero point (in the center of the scale) and shows
deviations in a positive direction (+5 thru +20) and in a negative direction
(-5 thru -20). The heading assumed by the student will be considered the
zero point and variations will be recorded from that heading.

TRANSITION TO CLIMB

This segment starts when the student increases pitch and/or power.

(1) Airspeed -

(2) Heading -   Measure for the duration of the segment.

(3) Start Time -   Start the stopwatch when the altimeter reaches
                    15200 ft.

TRANSITION TO CLIMB

AIRSPEED

① ├─────┼─────┼─────┼─────┼─────┤ KIAS

140   150   160   170   180

HEADING

② (-) ├─────────┼─────────┼─────────┤ (+) DEGREES

20   15   10   5   0   5   10   15   20
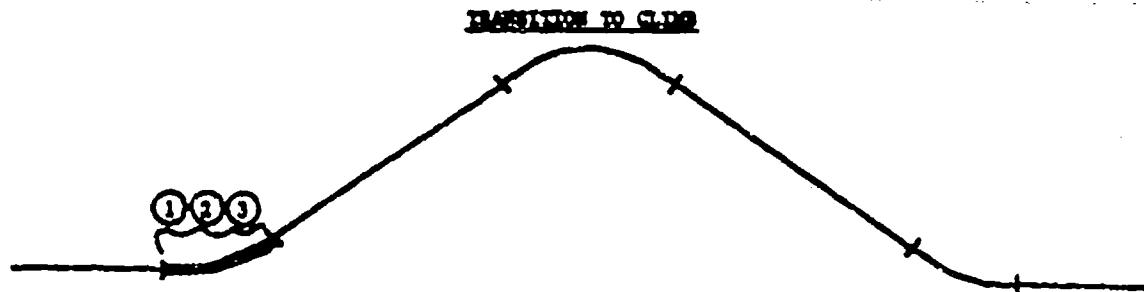
③   START TIME (START THE STOPWATCH).

CLDS

This segment starts after 300ft. of climb (approximately 15300')
and ends at 15800 ft.

④ Airspeed -　　⎫
⑤ Heading -　　⎬　Monitor and record throughout the segment
⑥ VVI　-　　⎭
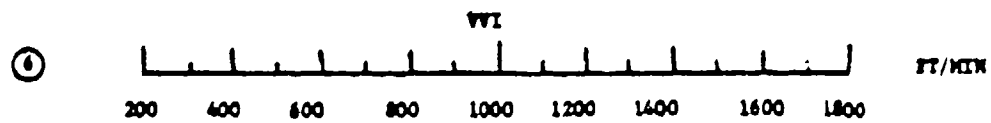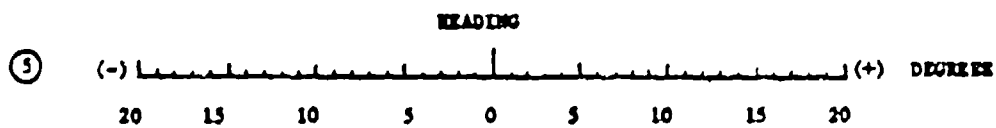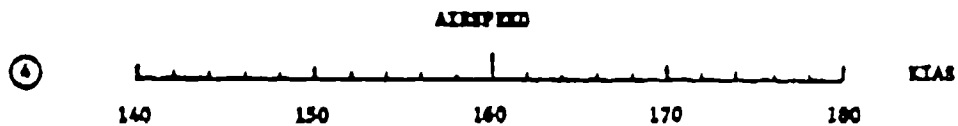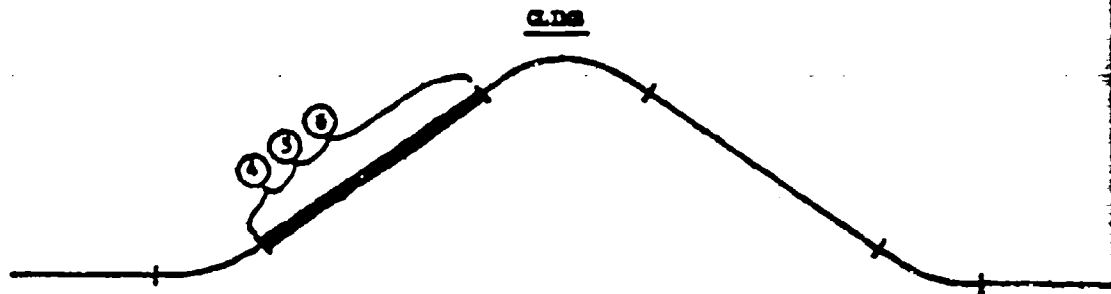
CLIMB

AIRSPEED

④ |_____|_____|_____|_____|_____|_____|_____|_____| KIAS

140   150   160   170   180

HEADING

⑤ (-) |_____|_____| (+) DEGREES

20   15   10   5   0   5   10   15   20

VVI

⑥ |_____|_____|_____|_____|_____|_____|_____|_____| FT/MIN

200   400   600   800   1000 1200 1400 1600 1800

TRANSITION TO DESCENT

This segment starts when a significant power/pitch decrease is observed.

(7)   Lead Point - Note the altitude when power/pitch decreases.

(8)   Power/Pitch - Rate the Togetherness/Smoothness for the segment.

(9)   Altitude - Mark the maximum altitude reached.

(10) Airspeed -

(11) Heading -   } Record deviations for the duration of the segment.

TRANSITION TO DESCENT

⑦ LEAD POINT

| 15700 | 15800 | 15900 | 16000 | 16100 | FEET |
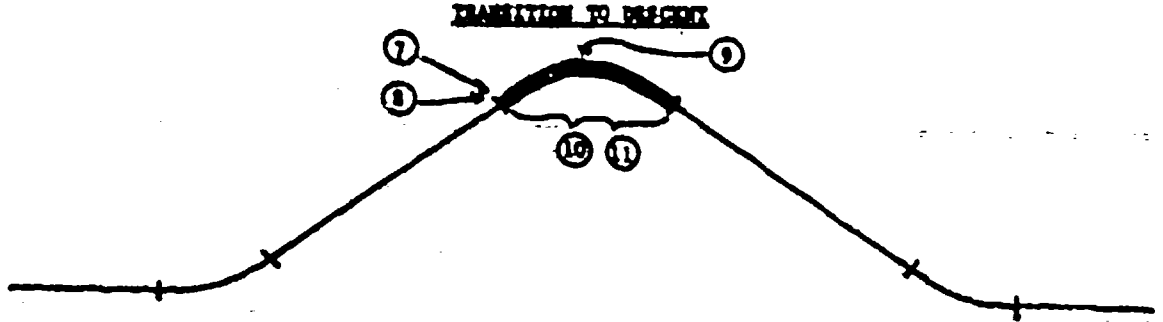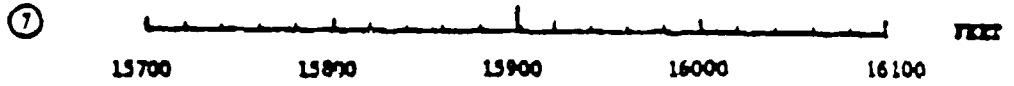
④ POWER/PITCH TOGETHER YES NO
SMOOTH YES NO

⑨ ALTITUDE

| 15800 | 15900 | 16000 | 16100 | 16200 | FEET |

⑩ AIRSPEED

| 140 | 150 | 160 | 170 | 180 | KIAS |

⑪ HEADING

(-) | 20 | 15 | 10 | 5 | 0 | 5 | 10 | 15 | 20 | (+) DEGREES
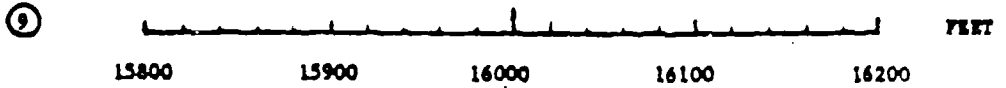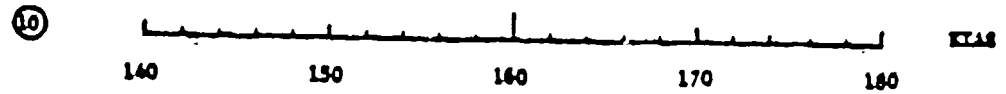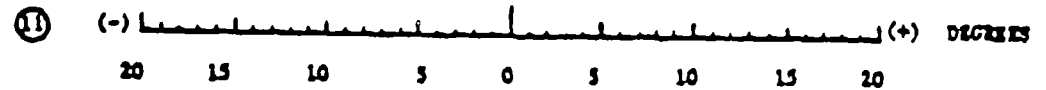
DESCENT

This segment starts when the altitude reaches 15800' and ends at
15300'.

⑫　Airspeed -　⎫
⑬　Heading -　⎬　Record variations throughout the segment.
⑭　VVI -　⎭

DESCENT

12. AIRSPEED
140 150 160 170 180 KIAS

13. HEADING
(-) 20 15 10 5 0 5 10 15 20 (+) DEGREES

14. VVI
200 400 600 800 1000 1200 1400 1600 1800 FT/MIN

LMVR-GTT
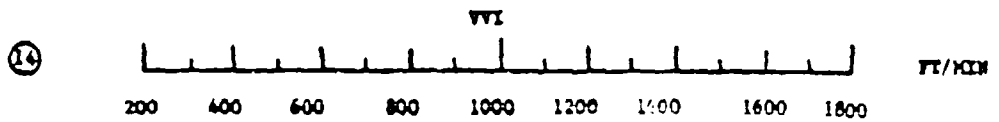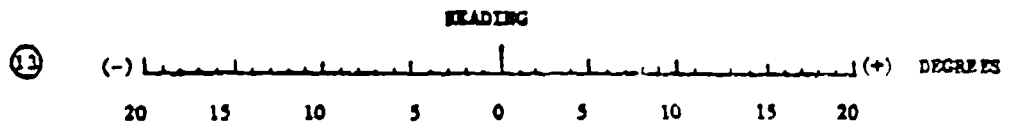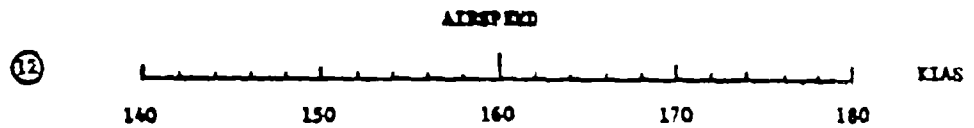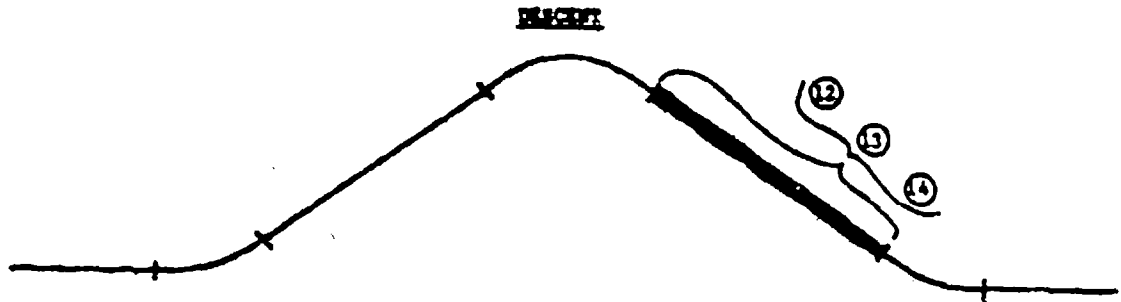
(15) Stop the stopwatch when the altitude reaches 15200' (and record in the space provided-- at the end of the maneuver).

(16) Lead Point - Record the altitude at which significant pitch and/or power increases are observed.

(17) Lead with power - Circle Yes or No.

(18) Airspeed -

(19) Heading -

Record and monitor after lead point and until straight and level flight is attained.
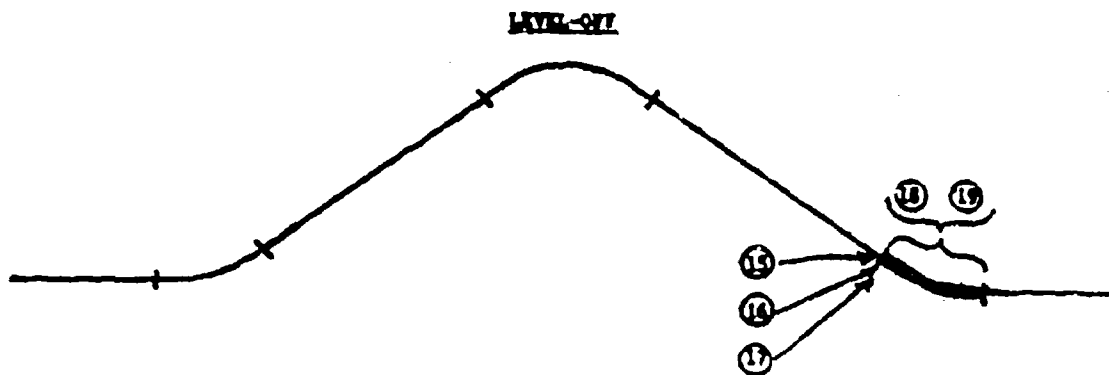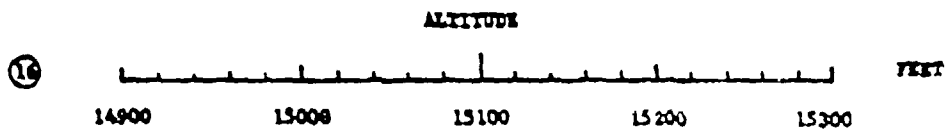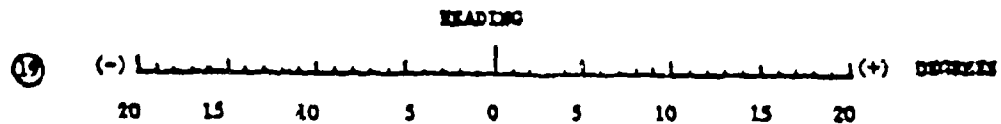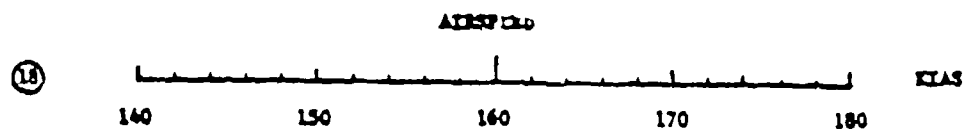
LEVEL-OFF

⑮   TIME AT 15200 ft. _____

ALTITUDE

⑯ |⌐—————————————————| FEET

14900   15000   15100   15200   15300

⑰   LEAD WITH POWER?   YES   NO

AIRSPEED

⑱ |⌐—————————————————| KIAS

140   150   160   170   180

HEADING

⑲ (-) |⌐—————————————————| (+) DEGREES

20   15   10   5   0   5   10   15   20
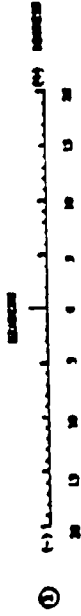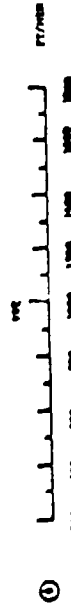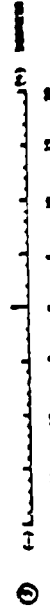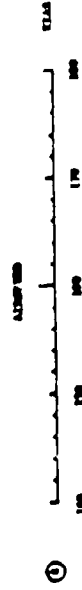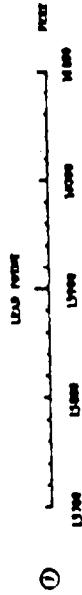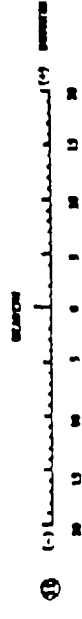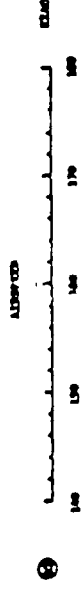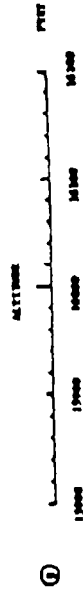
Appendix C

DESCENT
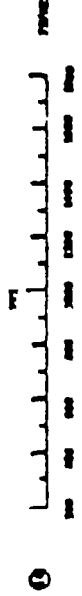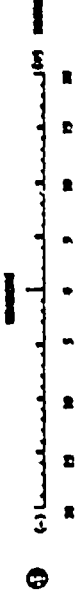
TRANSITION TO STRAIGHT & LEVEL

TRANSITION TO DESCENT

TRANSITION TO CLIMB

CLIMB
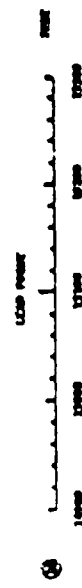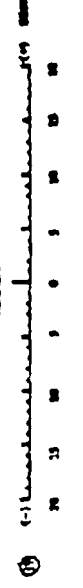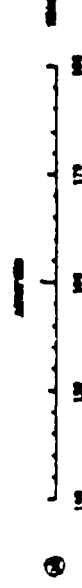
Appendix D

Table D-1

Analysis of Variance: Heading Deviation Range

Source of Variance	Sum cf Squares	df	Mean Square	F	p
Groups (G)	5.14	2	2.57	< 1	ns
Ss: G	152.75	27	5.66	-	-
Trial (T)	39.96	5	7.99	3.34	< .01
T X G	10.59	10	1.06	< 1	ns
Ss X T	322.95	135	2.39	< 1	ns

Table D-2

Analysis of Variance: Airspeed Deviation Range

Source of Variance	Sum or Squares	df	Mean Square	F	p
Groups (G)	23.47	2	11.74	< 1	ns
Ss: G	362.55	27	13.43	-	-
Trials (T)	118.16	5	23.63	11.53	< .01
T X G	23.26	10	2.33	1.14	ns
Ss X T	276.75	135	2.05	-	-

Table D-3

Analysis of Variance: Vertical Velocity Deviation Range

Source of Variance	Sum of Squares	df	Mean Square	F	p
Groups (G)	120.46	2	60.23	11.23	< .01
Ss: G	144.71	27	5.36	-	-
Trials (T)	9.54	5	1.91	3.60	< .01
T X G	18.17	10	1.82	3.43	< .01
Ss X T	70.89	135	0.53	-	-

Table D-4

Analysis of Variance: Time Maximum Deviation

Source of Variance	Sum of Squares	df	Mean Square	F	p
Groups (G)	5324.13	2	2662.06	7.73	< .01
Ss: G	9139.15	27	338.49	-	-
Trials (T)	573.32	5	114.66	2.34	< .05
T X G	2661.80	10	266.18	5.44	< .01
Ss X T	6611.55	135	49.97	-	-

Table D-5

Analysis of Variance: Maximum Altitude Deviation

Source of Variance	Sum of Squares	df	Mean Square	F	p
Groups (G)	8.72	2	4.36	< 1	ns
Ss X G	118.53	27	4.39	-	-
Trials (T)	8.99	5	1.80	< 1	ns
T X G	28.61	10	2.86	1.24	ns
Ss X T	312.07	135	2.31	-	-

Table D-6

Analysis of Variance: First Lead Point Maximum Deviation

Source of Variance	Sum of Squares	df	Mean Square	F	p
Groups (G)	188.81	2	94.41	3.87	
Ss: G	658.75	27	24.40	-	-
Trials (T)	54.89	5	10.98	1.89	-
T X G	90.13	10	9.01	1.55	
Ss X T	783.15	135	5.80	-	-

Table D-7

Source of Variance	Sum of Squares	df	Mean Square	F	p
Groups (G)	79.64	2	39.82	2.97	< .10
Ss: G	362.52	27	13.43		
Trials (T)	16.56	5	3.31	<1	
T X G	44.76	10	4.48	1.2	
Ss X T	518.18	135	3.84		