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TRANSFER FROM AUDIOVISUAL PRETRAINING TO A CONTINUOUS PERCEPTUAL MOTOR TASK

By

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March 1974
Final Report for Period June 1972 – August 1973

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WILLIAM V. HAGIN, Technical Director
Flying Training Division

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A technique was developed for providing transfer-of-training from a form of audiovisual pretraining to an instrument flight task. The continuous flight task was broken into discrete "categories of flight." Each category combined an instrument configuration with a return-to-criterion aircraft control response. Three methods of sequencing categories during pretraining were compared: (1) one group was pretrained by presenting categories in a natural task sequence, (2) a second group was pretrained on categories presented in random order; while

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(3) a baseline group received no category pretraining. Significant positive transfer was found for both the sequenced and random forms of pretraining relative to the baseline group. Transfer percentages ranged from seven to 48% throughout transfer practice.

SUMMARY

A technique was developed for providing transfer-of-training from a form of audiovisual pretraining to an instrument flight task. The continuous flight task was broken into discrete "categories of flight." Each category combined an instrument configuration with a return-to-criterion aircraft control response. Three methods of sequencing categories during pretraining were compared: (1) one group was pretrained by presenting categories in a natural task sequence, (2) a second group was pretrained on categories presented in random order; while (3) a baseline group received no category pretraining. Significant positive transfer was found for both the sequenced and random forms of pretraining relative to the baseline group. Transfer percentages ranged from seven to 48 per cent throughout transfer practice.

PREFACE

This in-house research was conducted under Project, USAF Flying Training Development, Task 113801, entitled "Cognitive Components of the Flying Task".

The research was carried out in partial fulfillment of the senior author's PhD requirements in Educational Technology from the Arizona State University, Tempe, Arizona.

Special appreciation is extended to Dr William V. Hagin, Technical Director of the Flying Training Division, and Lt Colonel Dan D. Fulgham, Chief of Flying Training Division, for the direct assistance extended in support of this research.

Transfer from Audiovisual Pretraining To a Continuous Perceptual-Motor Task

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One distinctive human characteristic is the ability to perform a continuous, complex perceptual-motor task with precision and reliability. Traditionally, perceptual-motor tasks are taught using apprenticeship instruction. During instruction, emphasis is placed on the use of the actual vehicle and task. Three recent developments have led to a need for more efficient techniques for developing perceptual-motor skill.

First, the dollar cost associated with the purchase and maintenance of criterion devices such as airplanes and automobiles continue to increase. Secondly, the air or ground space needed for initial practice of the criterion task is often not available or is easily polluted. Thirdly, as the general complexity of many perceptual-motor tasks increases, fewer criterion practice situations are available which provide an acceptable learning environment for the novice.

To reduce some of these problems, modern instructional technology provides a number of training techniques to facilitate motor skills instruction. For example, the training effectiveness of simulators and part-task trainers has been clearly demonstrated. However, these devices are becoming so sophisticated and costly that efforts must be made to define least-cost training techniques which can precede, augment or replace existing forms of simulator or part-task instruction.

Research regarding (1) the strong conceptual nature of the perceptual-motor task, and (2) techniques for providing stimulus pretraining seem particularly promising as sources for new least-cost training techniques. Recent work by Posner and Keele (1971) highlights the notion of conceptual "motor programs" which serve to drive complex motor behavior. Similar constructs are offered by Attneave (1957) and Oldfield (1954) under the general rubric of conceptual "schema." In the area of stimulus pretraining, significant transfer-of-training has been shown when stimulus pretraining was used for discrete, discrimination-type motor tasks. The research in this area, including studies on stimulus predifferentiation, sensory preconditioning, and acquired distinctiveness of cues, leads one to believe that these principles could be used to train Ss in the cognitive "motor programs" or "schema" which direct subsequent motor behavior. The efficient use of this general approach has not been generally employed in perceptual-motor training.

The objectives of this study were: (1) to develop a method for describing a continuous, complex perceptual-motor task in discrete cognitive terms by which Ss could be pretrained through use of static, programmed, audiovisual techniques; (2) to construct an audiovisual training device to provide realistic, programmed practice in the stimulus-response events selected for pretraining; and (3) to conduct a comparative experimental study to determine the relative levels of transfer-of-training between three pretraining treatments and the transfer task.

METHOD

Forty-five male volunteer Ss were randomly assigned to one of three groups of 15 Ss. All Ss were adult males between the ages of 18 and 28, and had no previous piloting experience.

Figure one shows the light airplane instrument trainer with simulated motion (i.e., the Link GAT-1), used to provide the training environment for the transfer task. The GAT-1 was operated only in the pitch dimension, thus restricting the instrument flight task to straight ahead variations in pitch and altitude only. A random "rough air" perturbation was used as a forcing function, while S error in pitch and altitude was integrated over time (i.e., absolute integrated error) through use of an analog computer. Temporal measures of trial and intertrial interval, time to level-off, and level flight time were recorded through use of interval and clock counters.

Figure two shows the Audiovisual Cockpit Trainer (ACT) constructed to provide pretraining sequences. The ACT was

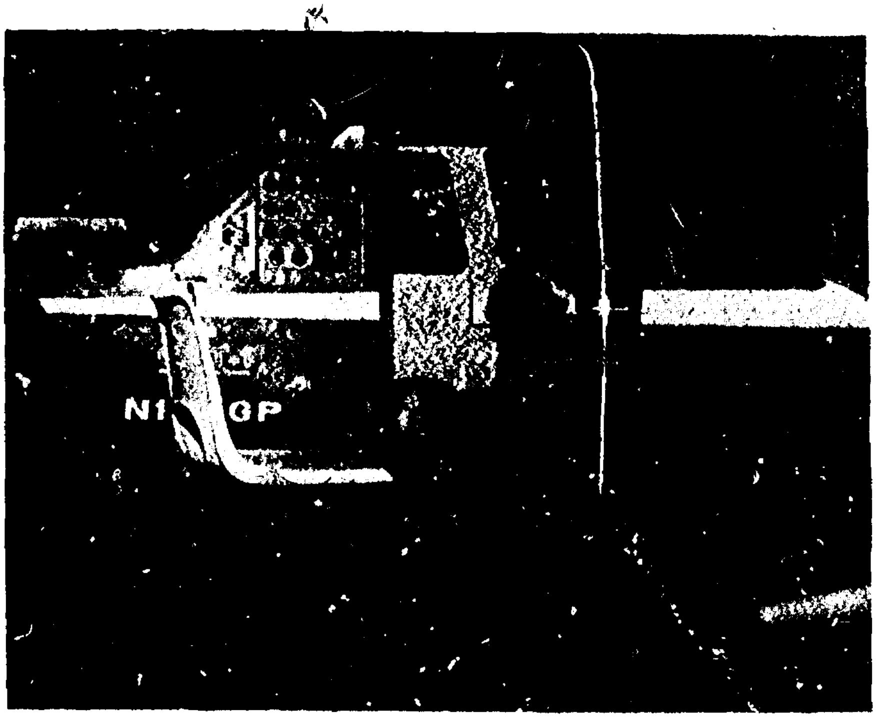

Fig. 1. Link General Aviation Trainer (GAT-1).

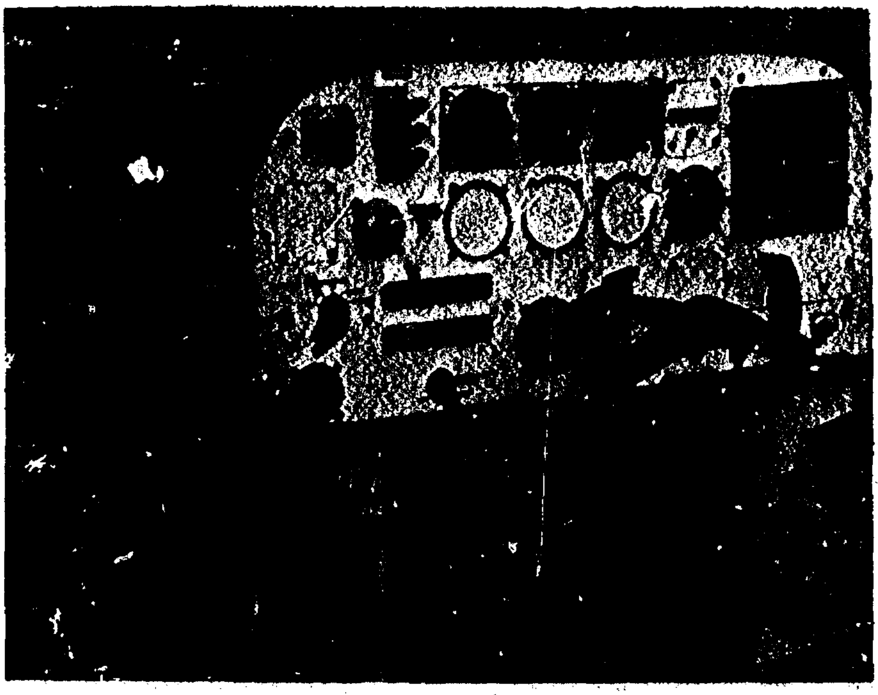

Fig. ?. Audiovisual Cockpit Trainer (ACT).

designed to represent the GAT-1 cockpit and provided: (1) wheel control; (2) a rear projection screen which represented the "instrument panel" of the GAT-1; and (3) a series of three lights which were used for feedback purposes. All dimensions and spatial relationships of the GAT-1 were preserved in the ACT. To provide open-loop wheel (pitch) responses to various instrument configurations, 35mm slides were displayed on the ACT "panel" by means of rear projection. Slide sequencing and audio instruction were provided by a cassette loaded tape programmer. Micro-switches positioned on the wheel assembly provided indications of S response for performance measurement and the display of knowledge-of-results. Accuracy and latency of response measures were obtained for all criterion test events. See Appendix I.

The following procedure was used for representing the instrument flight task in discrete terms for pretraining purposes: (1) the specific instruments involved in the criterion task were identified; (2) only three states were allowed for each instrument, i.e., greater than, equal to, or below a stated criterion; (3) all combinations of the selected instruments across three states were calculated; and (4) only those instrument combinations likely to be encountered in transfer performance were selected for pretraining purposes. See Appendix II for details.

Having selected a set of instrument "categories" appropriate for pretraining use, a pitch response was selected for each flight category which would initiate a simulated return to the criterion flight condition. For example, the category "pitch high, altitude high" would require a wheel forward response to initiate a return to altitude. The category "pitch low, altitude low" would require a wheel back response to initiate a return to altitude. Inherent in this procedure is the definition of a set of mutually exclusive instrument configurations which represent the criterion task, but which can be manipulated in a number of different ways for pretraining purposes. It also provides a set of instrument-response categories which, taken singly or together, provide a general strategy for moving from a state of error to a "correct" criterion condition.

In terms of the present study, two variations in instructional sequence were explored. One group of 15 Ss received pretraining in flight categories which were sequenced in a natural task order, while a second group of 15 Ss were trained in the same flight categories presented randomly. A third, or baseline group of 15 Ss received no pretraining on flight categories, but did receive a form of pretraining which acquainted Ss with single-instrument reading skills only.

As shown in Figure 3, the experimental design required two experimental sessions presented on two consecutive days. On the first day, all Ss were given a simple reaction time test, and were required to read a simple "air to ground" message of the kind used for time sharing during the last six trials of transfer performance. Following a short audiovisual

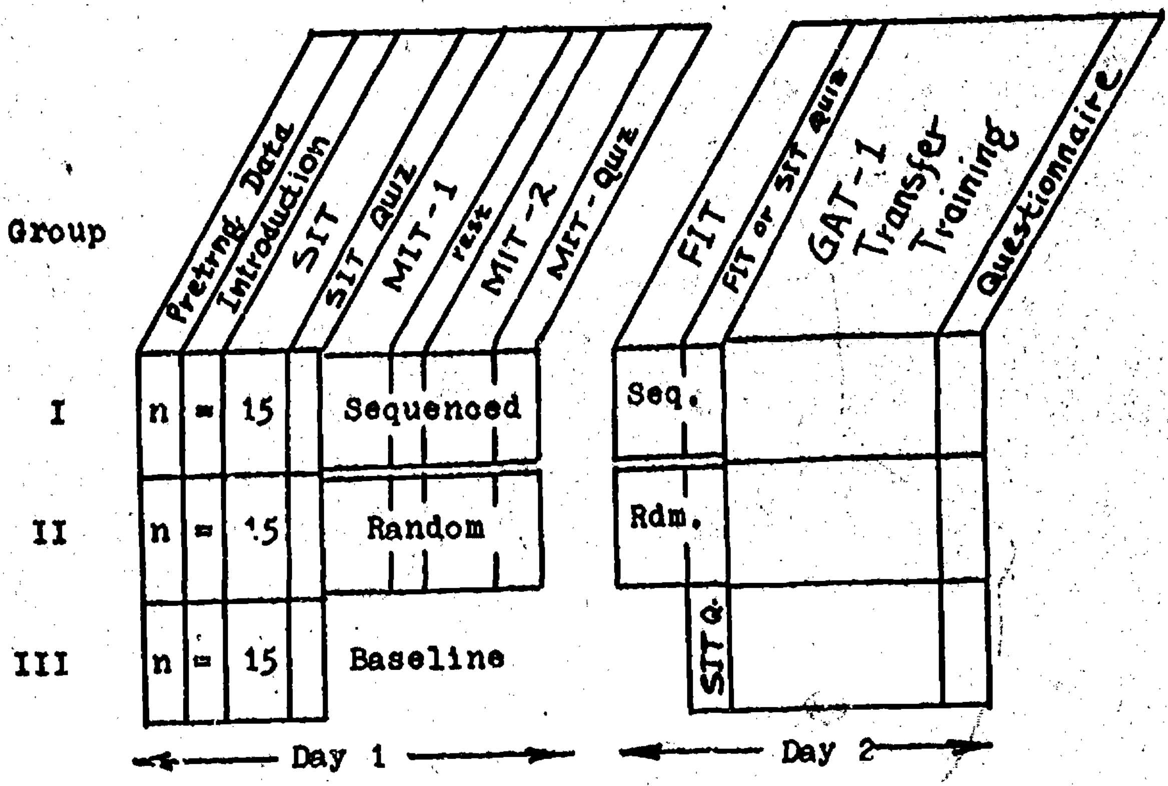

Fig. 3 Block diagram of experimental design showing temporal sequence of training events. Simple reaction time and message reading data were obtained under the heading Pretraining Data. Other abbreviations are as follows: SIT=Single Instrument Training; MIT=Multiple Instrument Training; and FIT=Final Instrument Training.

"introduction" program, all Ss received a linear, programmed sequence on how to read pitch or altitude instruments when presented singly. During this instruction, Ss used switches located on the ACT panel to make identification responses to questions presented on 35mm slides. A criterion test was administered after single instrument training. Following completion of this phase of instruction, the two experimental groups were given either sequenced or random pretraining on selected flight categories (i.e., multiple instrument training). Wheel responses were made during this phase of instruction, with linear programming techniques being used to guide Ss through a total of 18 exposures to each flight category. A criterion test which required responses to flight categories presented in both a sequenced and random fashion were given after this training.

On the second day, baseline Ss were re-examined in single instrument reading skills, and then given practice in the transfer GAT-1 task. Experimental Ss received brief pretraining sequences of either a sequenced or random nature, followed by a "final practice" criterion test and practice on the transfer task.

The transfer task is shown schematically in Fig. 4. Ss were required to: (1) make a controlled climb or descent of 200 feet to an altitude of 3000 feet; (2) maintain level flight at 3000 feet for 40 seconds; and (3) establish a controlled climb or descent until the termination of a trial. Twelve two-minute trials were presented, followed by an

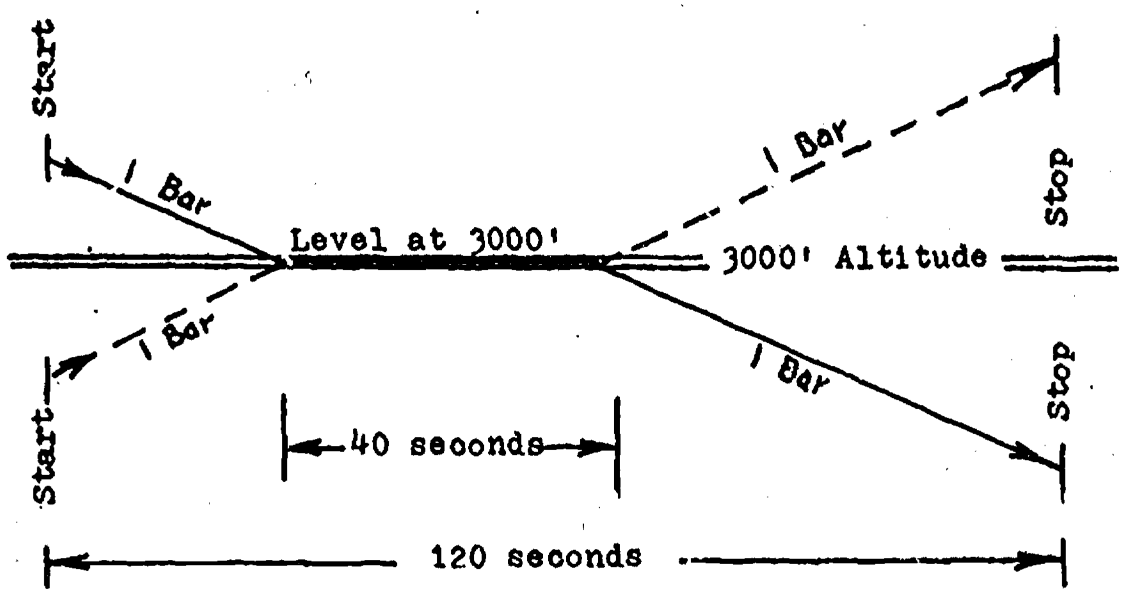

Fig. 4. Flight profile (i.e., ideal) of transfer task.

additional six trials in which Ss were required to read a message while performing the level-flight portion of the task. Trials were blocked by pairs of two for statistical analysis.

RESULTS AND DISCUSSION

A first measure of transfer performance in the GAT-1 was time-to-level-off. To obtain this measure, Ss were timed as they climbed or descended through 200 feet altitude at a 500 fpm rate. At 500 fpm, 24 seconds were required to move through 200 feet of altitude. Variations from this 24 second ideal were used as the time-to-level-off error measure. A natural log transform was applied to the raw data to reduce positive skew (Winer 1962). Figure 5 shows these data.

Based on a repeated measure analysis of variance (Lindquist Type I), significant between S differences were found, $F(2, 42)=11.1355$, $p<.0003$. Post hoc analysis of simple main effects showed significantly less error for sequenced trained Ss relative to baseline S during trials 7-8, $p<.001$, and trials 13-14, $p<.05$. Significant simple main effects were also found between baseline and random trained Ss at trials 15-16, $p<.01$, and trials 17-18, $p<.05$. The reliability coefficient, as estimated by Hoyt's (1941) analysis of variance procedure, yields $r=.606$.

To more clearly display the direction and amount of transfer, Fig. 6 shows the time-to-level-off data in terms of per cent transfer. The Murdock (1957) formula was used where.

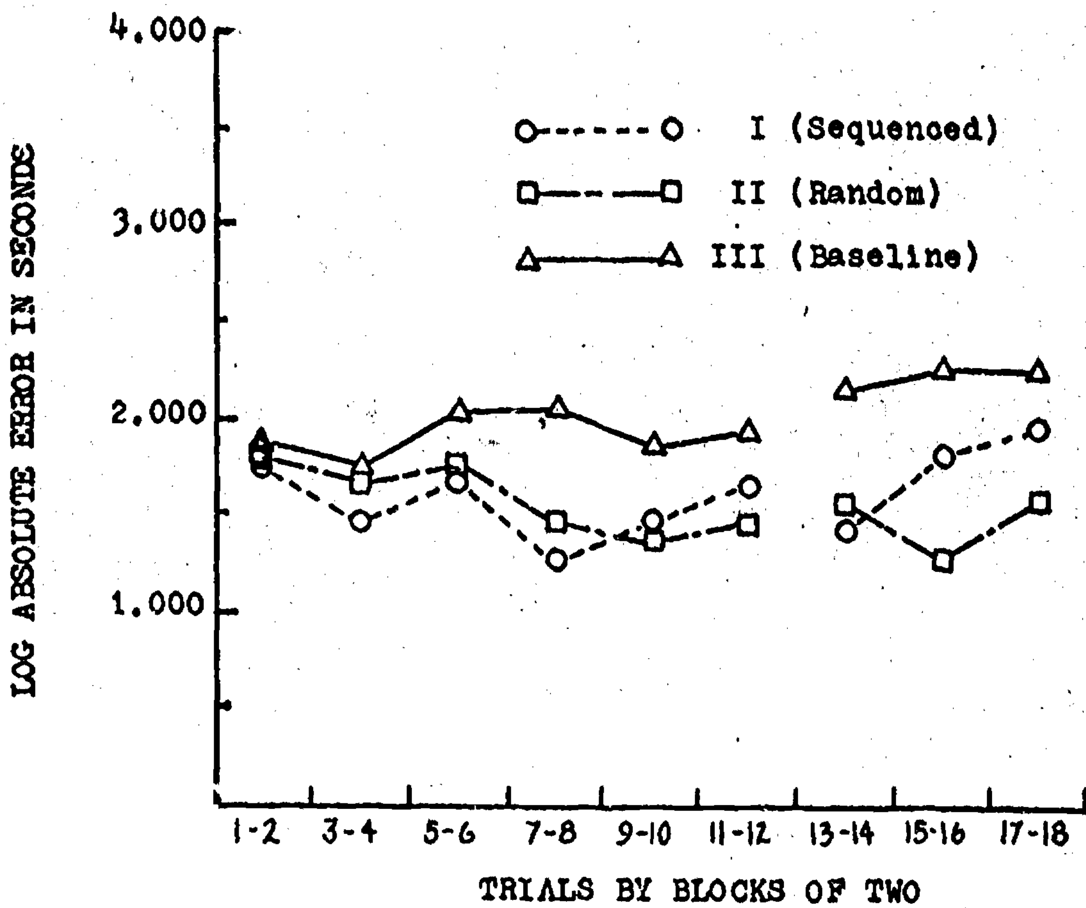

Fig. 5. Mean absolute time-to-level-off error relative to 24-second-ideal.

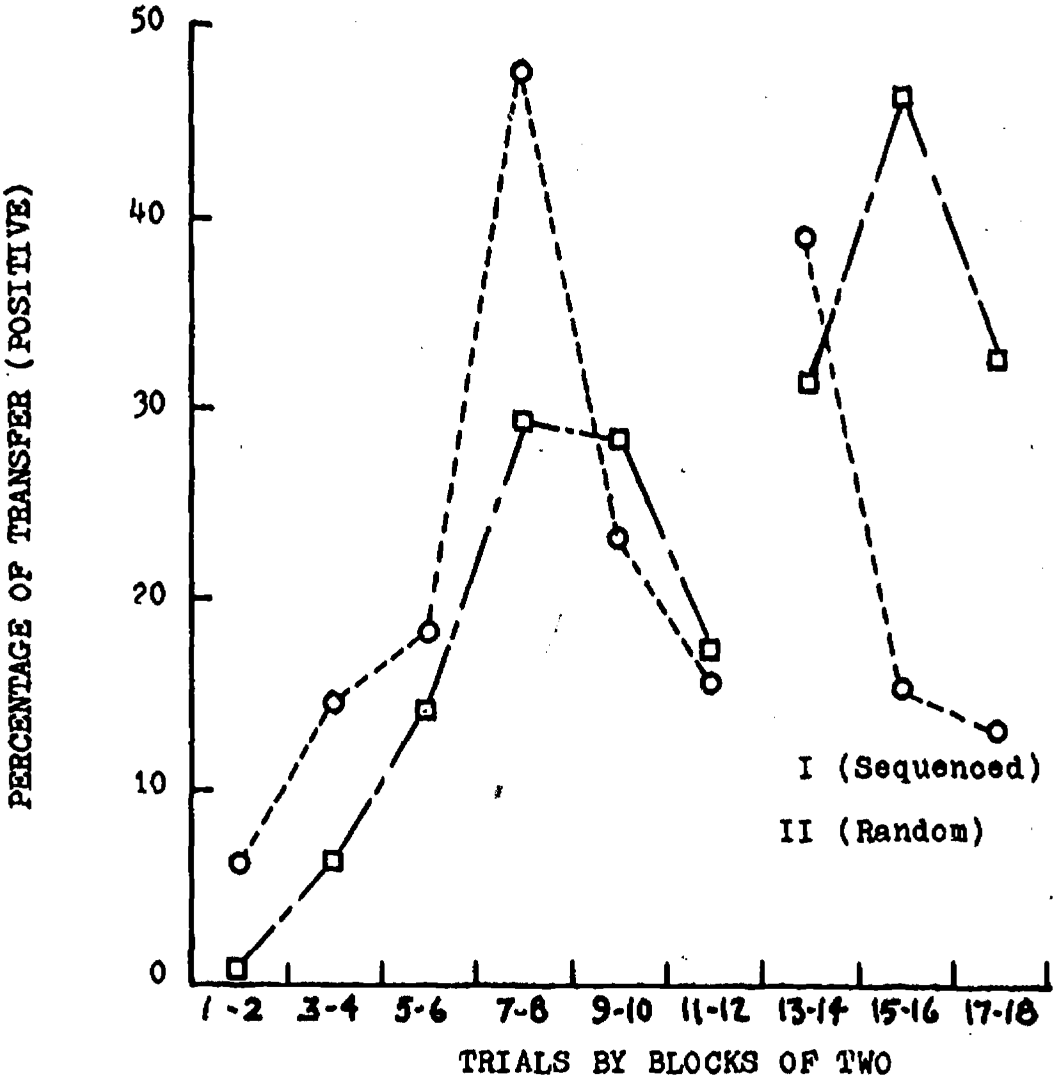

Fig. 6. Percentage of transfer for Time-To-Level-Off measure.

$$\text{Percentage of transfer} = \frac{\text{Experimental Score-Control Score}}{\text{Experimental Score+Control Score}} \times 100.$$

Log transform scores were squared prior to use in this formula to provide a best compromise between raw and log transformed data (Myers, 1966).

The profiles of Fig. 6 show transfer effects increasing with practice. During trials 15 through 18, random trained Ss show sustained transfer effects around the 40 per cent level.

A second transfer measure was a combination of two absolute integrated pitch error scores, i.e., pitch error obtained before level off plus pitch error obtained after termination of level flight. Figure 7 shows these data. To reduce positive skew, data were again transformed to natural logs. A Type I ANOVA showed significant between Ss effects, $F(7, 47)=3.446$, $p<.04$. Post hoc analysis of simple main effects showed early differences between baseline and experimental groups. Sequenced trained Ss were significantly better than baseline during trials 1-2, $p<.01$ trials 3-4, $p<.05$. and trials 5-6, $p<.05$. Random trained Ss showed significant gains during trials 1-2, $p<.01$, and trials 5-6, $p<.05$. Test reliability, as estimated by Hoyt's (1941) procedure, gives $r=.758$.

Figure 8 shows the approach plus departure pitch data as per cent transfer. The Murdock (1957) formula and squared log scores (Myers, 1966) were again employed. Relative to this measure, lesser amounts of transfer occur. Only early

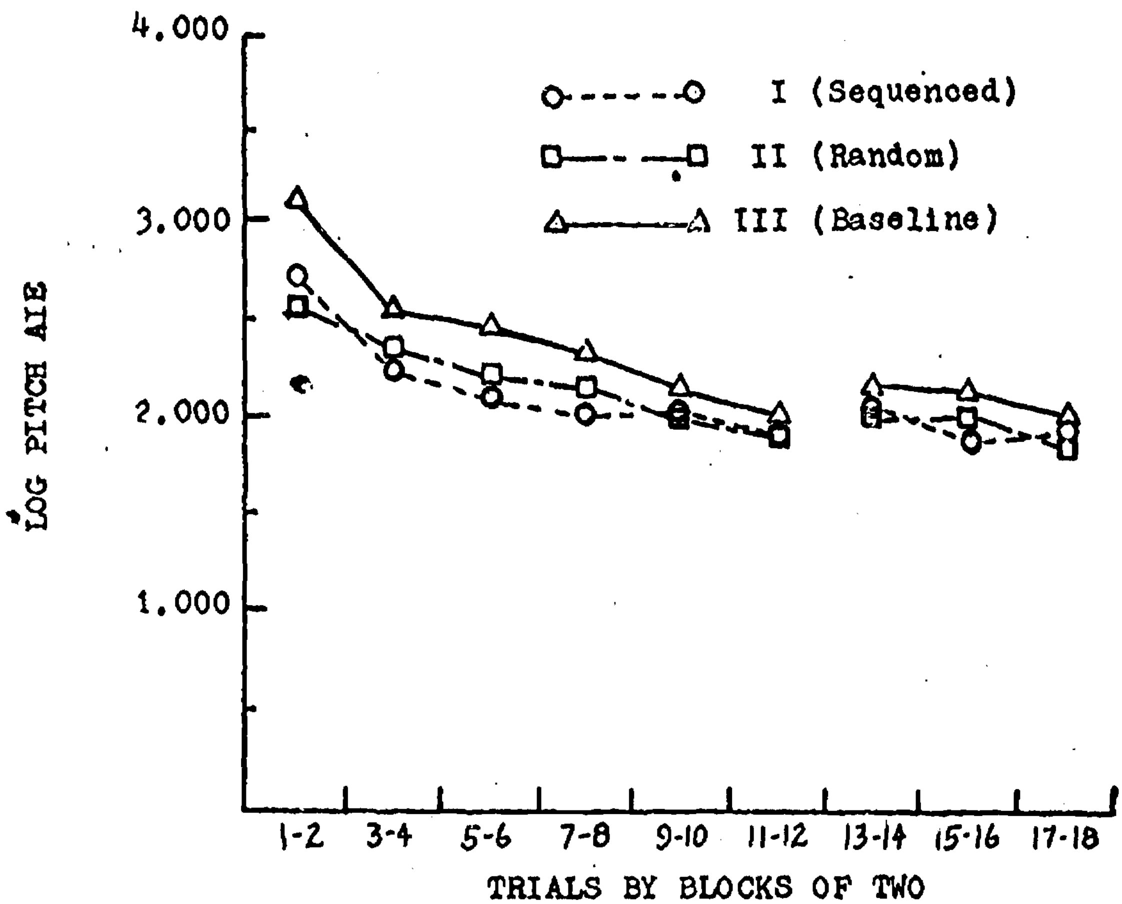

Fig. 7. Mean Approach-Plus-Departure-Pitch error (Log AIE) as a function of transfer practice.

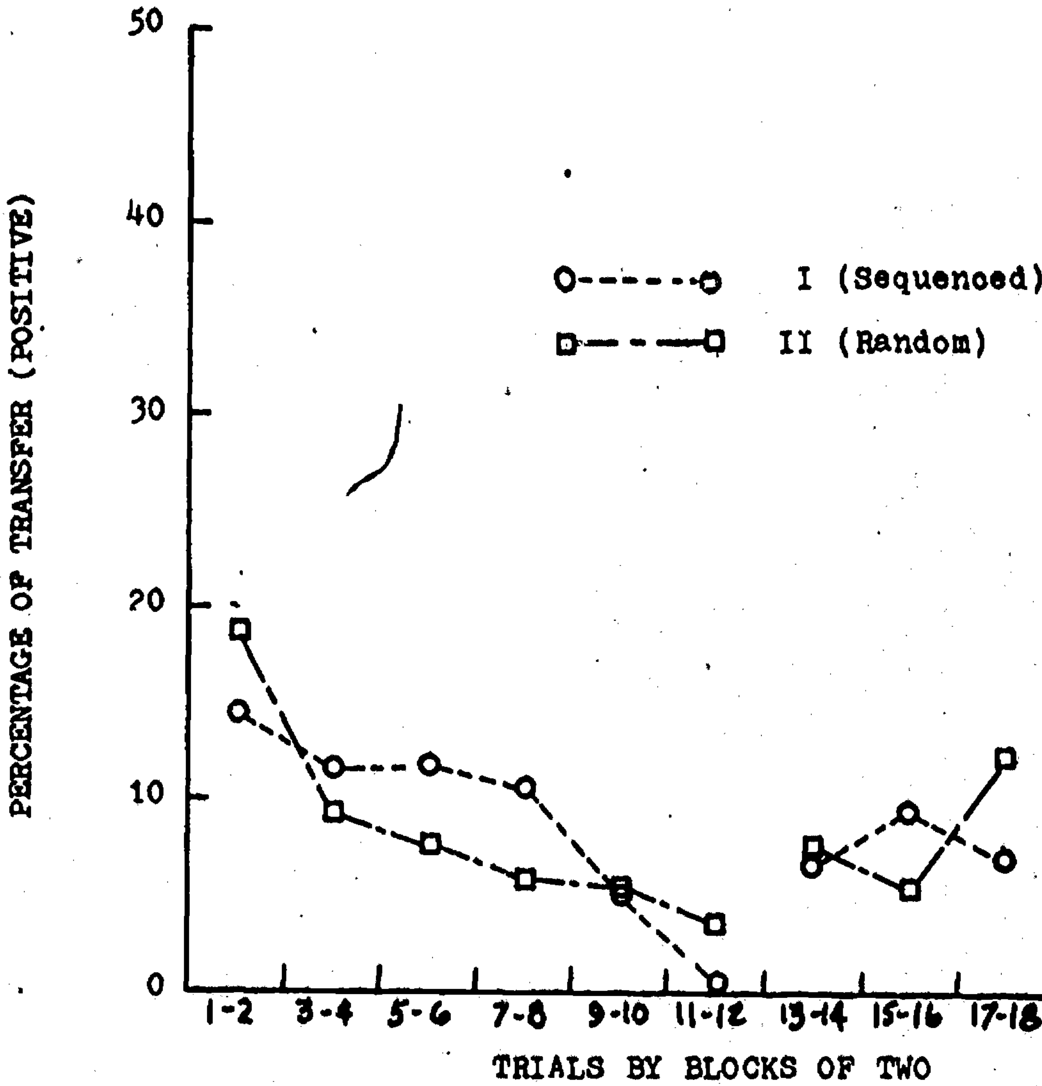

Fig. 8. Percentage of transfer for Approach-Plus-Departure-Pitch measure.

significant effects are apparent, i.e., trials 1 through 6, with per cent transfer ranging from 18 per cent to 7 per cent.

A final set of measures reflect performance during the level flight portion of transfer practice. Figure 9 shows these data. Absolute Integrated Error was obtained for both pitch and altitude. Natural log transforms were used to reduce positive skew. Type I ANOVA showed no significant differences for the pitch error measure. However, significant findings were observed for altitude error, $F(2, 42)=4.057$, $p<.0239$. Post hoc analysis of simple main effects showed significantly less error for sequenced trained Ss relative to baseline Ss during trials 1-2, $p<.05$, trials 3-4, $p<.05$, and trials 17-18, $p<.05$. Similar significant results were shown for random Ss relative to baseline during trials 11-12, $p<.01$, and trials 17-18, $p<.05$. Test reliability, as estimated by Hoyt's (1941) procedure, gives $r=.839$.

By squaring the log scores (Myers, 1966) for use in the Murdock (1957) per cent transfer formula, the data of Fig. 10 is generated. In the altitude control task, both forms of pretraining provide transfer percentages that range from 16 to 24 per cent. Transfer effects also appear to persist throughout all 18 transfer trials.

Considering the transfer data, several useful conclusions can be drawn. Of primary importance was the finding that a complex, continuous, perceptual-motor task can be pretrained using programmed, sound-slide techniques. Transfer

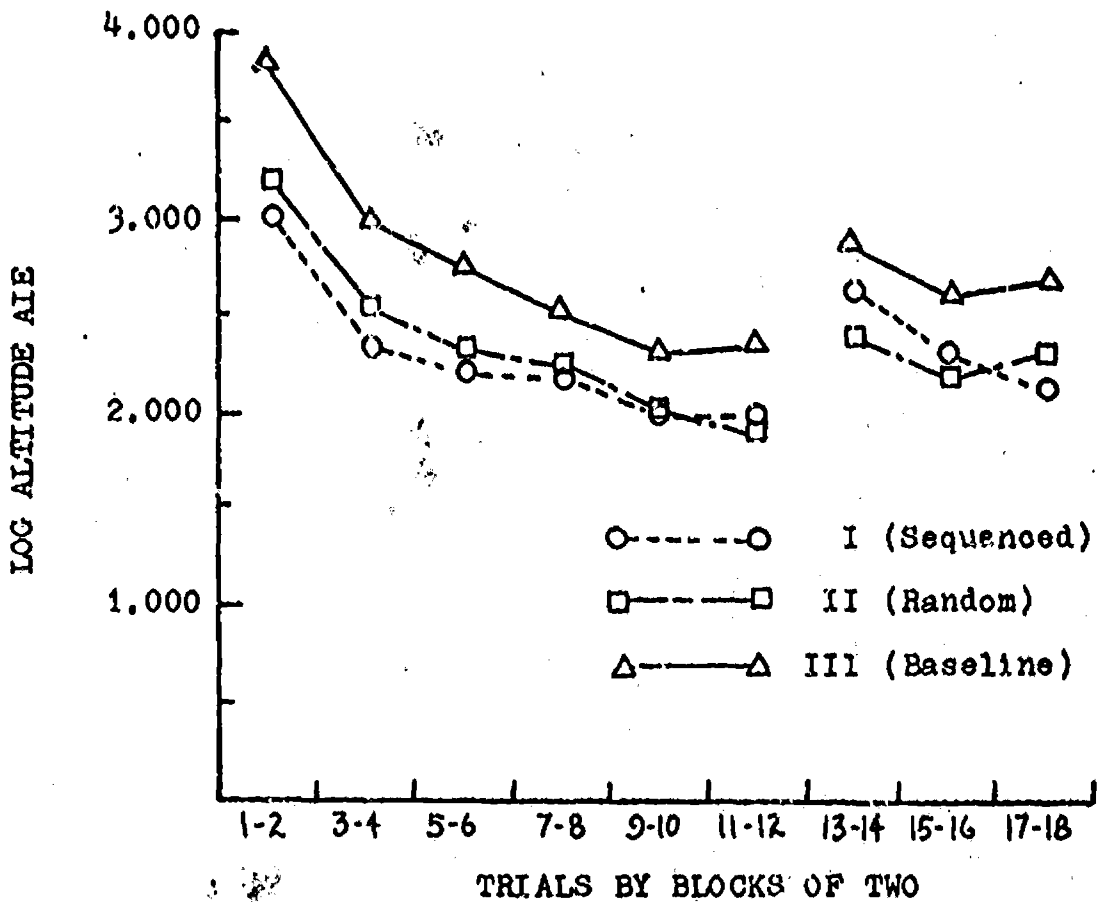

Fig. 9. Mean altitude error during level flight (Log AI E) as a function of transfer practice.

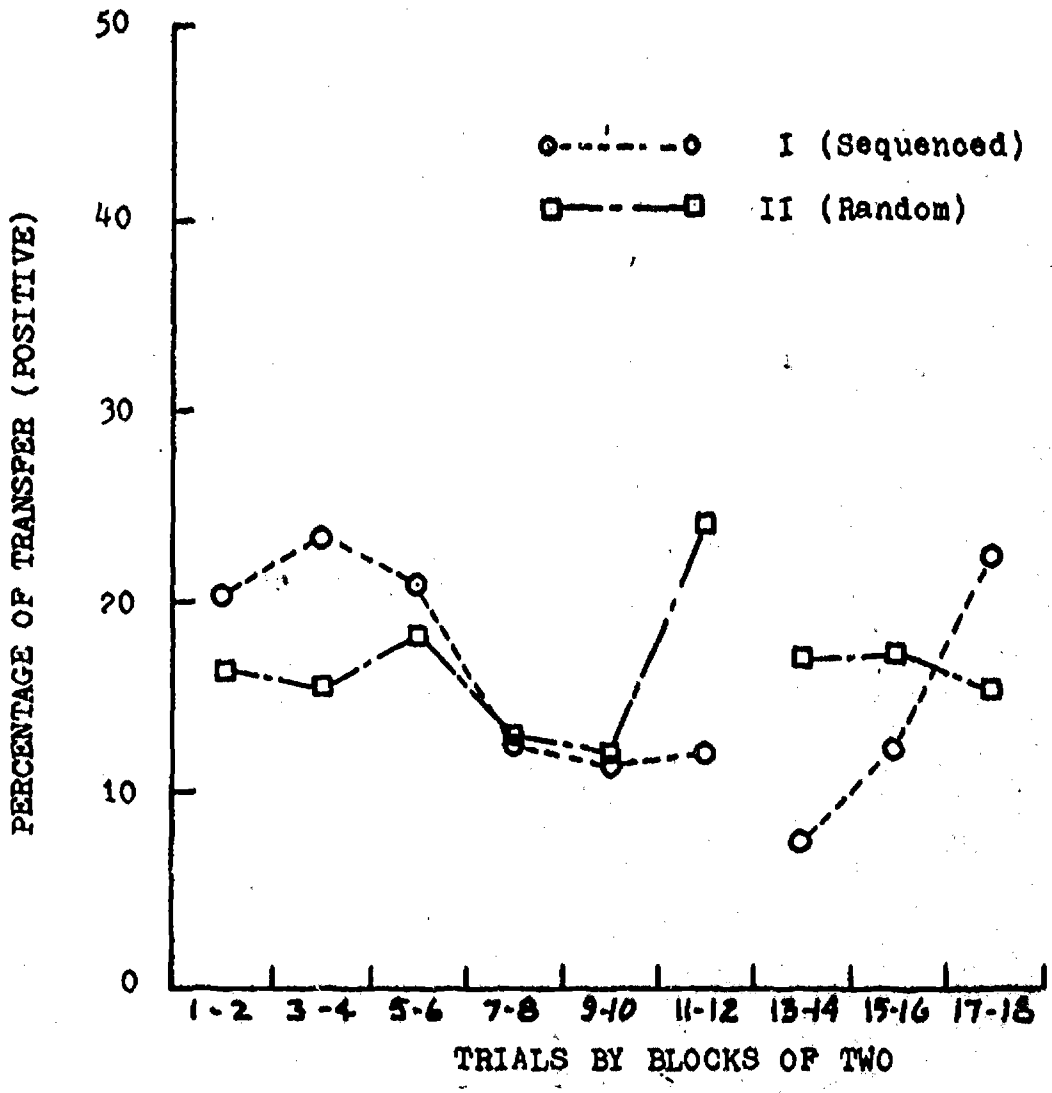

Fig. 10. Percentage of transfer for Altitude-During-Level-Flight measure.

percentages ranging from seven to 48 per cent throughout transfer practice suggest a pretraining technique of definite practical potential. The immediate and sustained indication of positive transfer during transfer practice provides clear support for a relevant stimulus, relevant response form of pretraining. Support is also given to the category method of separating a continuous task into discrete parts, and the notion of training Ss in error correction strategies rather than a specific representation of the maneuver, (e.g., maintaining level flight when return to level flight was the only task pretrained). The results of this study also reduce concern over pretraining characteristics which could have provided negative transfer effects. The open-loop nature of practice, lack of control "feel," fixed aircraft control excursions, and no instrument movement represents factors of this nature.

A lack of significant differences between random and sequenced pretraining does not support the existence of major differences between these treatments. A tendency for random pretraining to provide a more sustained effect relative to baseline is seen in the last four trials of time-to-level-off. Random trained Ss also show sustained transfer effects during trials 11-12 and 17-18 of the altitude-during-level-flight measure. Considering the weak nature of these findings, however, real differences between sequenced and random pretraining are only suggested. It may be that future research will show advantages for a random form of training not determined in this study. For example, in the present study it must be assumed that random trained Ss learned the sequential dependency of the criterion task by their own methods. This learning could occur during pretraining through S logic, and/or during transfer practice. If S can quickly learn the sequential aspects of a task in this way, a well constructed random pretraining sequence could provide S with successful pretraining in the basic stimulus-response elements of a large class of maneuvers. Should this occur, the flying training student would have opportunity to practice the task elements of flight much as the musician practices the "scales" of music to better subsequent performance.

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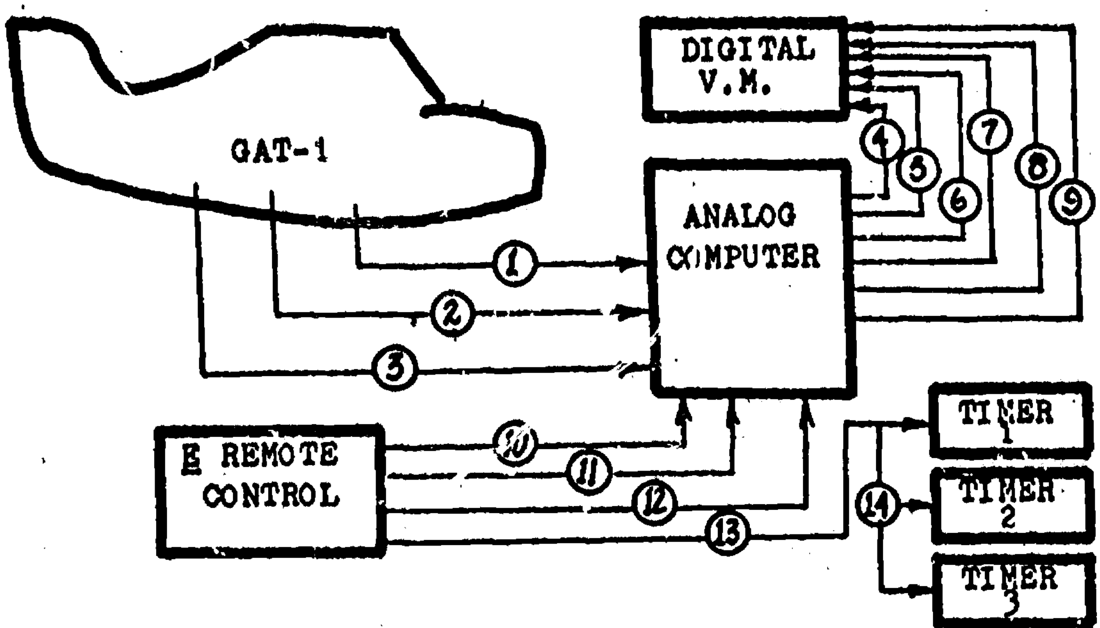
APPENDIX I

Functional diagrams of GAT-1 and ACT circuitries.



<u>GAT-Output</u>

1. D.D. pitch error
2. D.C. altitude error
3. D.D. forcing function

<u>Analog to Digital VM</u>

4. Pitch AIE
5. Altitude AIE
6. VSI
7. Altimeter
8. Forcing function
9. Reference voltage

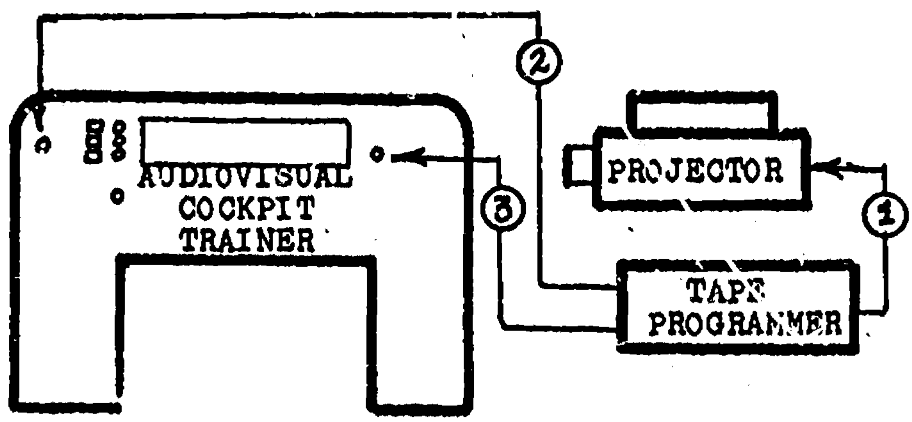
<u>E Remote Control</u>

10. Analog reset
11. Pitch climb/level/dive bias
12. Pitch/altitude selector
13. Trial start
14. Timing circuitry

<u>Timers</u>

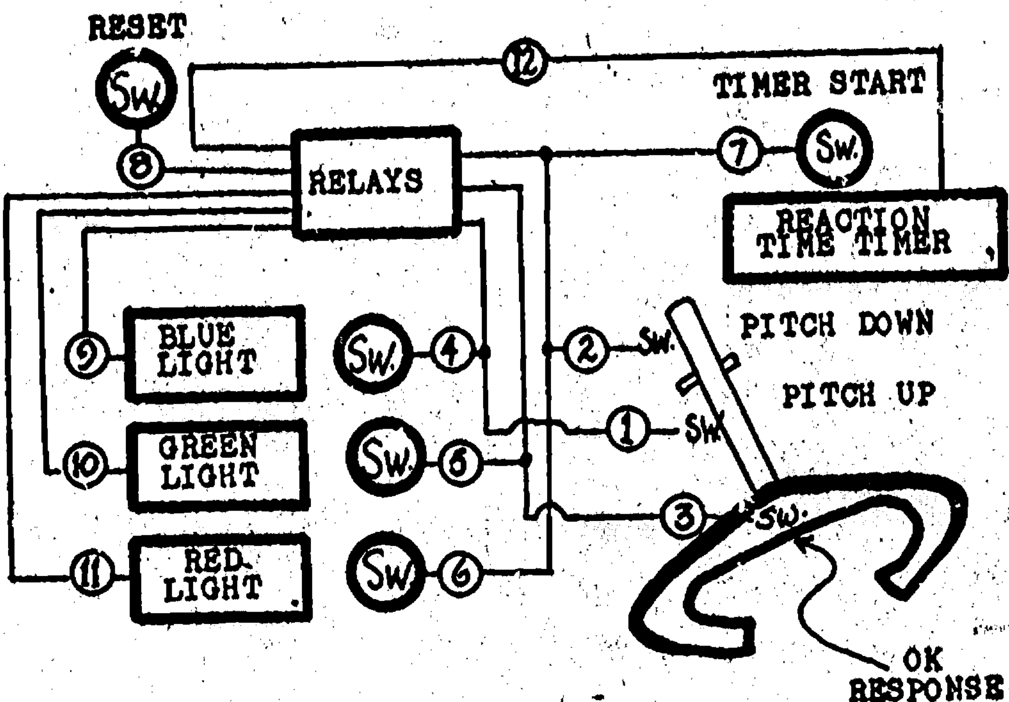
1. Trial interval timer
2. Pitch clock counter
3. Level flight clock counter

Functional circuit diagram of transfer equipments



1. Slide synchronizer cord
2. Audio out for headphones
3. Tape programmer restart

Functional diagram of external ACT components.



<u>Switched Inputs</u>

1. Pitch up (wheel back)
2. Pitch down (wheel forward)
3. "OK" pitch response
4. Above response
5. Equal response
6. Below response
7. Reaction time start

<u>Reset</u>

8. Reset switch

<u>Relay Out</u>

9. Blue light
10. Green light
11. Red light
12. Reaction time stop

Functional diagram of ACT response and feedback circuits.

APPENDIX II

RULES FOR FORMING FLIGHT CATEGORIES

1. Select instruments needed for performance of the task. In the present study, only the altimeter and the pitch indicator of the artificial horizon was used.

2. Select the flight criterion (criterions) which represent desired performance. Level flight at 3000 feet was selected as the criterion task.

3. Allow only three states to exist for any given instrument, i.e., greater than, equal to, and less than criterion. Equivalent states for an altimeter would be high, OK, low. States for pitch wuld be up, level, and down.

4. Plot all possible combinations by instruments and states. The nine combinations for altitude and pitch are shown below. The maximum number of combinations equals the number raised to a power equal to the number of instruments, thus $3^n = 3^2 = 9$ categories.

Category	Altitude	Pitch
1	High	Up
2	High	Level
3	High	Down
4	OK	Up

Category	Altitude	Pitch
5	OK	Level
6	OK	Down
7	Low	Down
8	Low	Level
9	Low	UP

5. Select those categories of flight likely to be encountered during practice, or those which are to be manipulated for experimental purposes. In the present study, emphasis was placed upon error correction strategies, i.e., training Ss to return to 3000 feet. Because the middle three categories represent flight at 3000 feet, they were not included in the pretraining regime.

6. Assign appropriate responses to the categories selected for use. The assignment of responses for this study is as follows:

Category	Altitude	Pitch	Wheel Response
1	High	Up	Wheel forward
2	High	Level	Wheel forward
3	High	Down	OK
4	Low	Down	Wheel back
5	Low	Level	Wheel back
6	Low	Up	OK

7. <u>Subdivide a given category with corollary response rules if required.</u> The present study required training of one-bar descents and level-offs for categories three and six. The final flight categories, with limiting instrument conditions, are:

Category	Altitude	Pitch	Condition	Wheel Response
1	High	Up	Any	Forward
2	High	Level	Any	Forward
3a	High	Down	1 bar	OK
3b	High	Down	>1 bar	Back
3c	High	Down	>40 feet	Back
4	Low	Down	Any	Back
5	Low	Level	Any	Back
6a	Low	Up	1 bar	OK
6b	Low	Up	>1 bar	Forward
6c	Low	Up	>40 feet	Forward