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CUES AND PRACTICE IN FLYING TRAINING

Fritz H. Brecke

April 1975

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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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Vernon S. Gerlach, Principal Investigator

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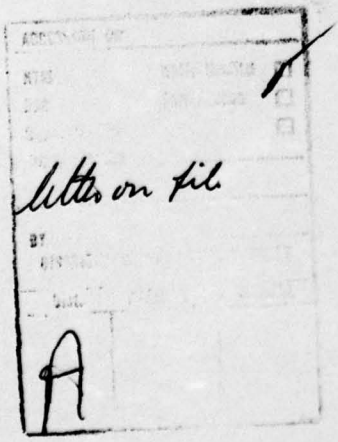
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Contents

Section	Page
Problem and Antecedents	1
Research Background	8
Theoretical Framework	8
Related Research	13
Mental Practice	13
Verbal Pretraining	16
Differential Instructions	19
Summary	21
Variables and Hypotheses	22
Independent Variables	22
Dependent Variables	23
Hypotheses	23
Method	25
Subjects	25
Apparatus	26
Treatment Materials	26
Levels of Instructional Cues	27
Currently Operational Cues	27
Systematically Developed Cues	28
Levels of Practice	28
Program Development and Validation	28
Design	32
Procedure	32
Data Collection and Analysis	35

Section	Page
Results	38
Cognitive Performance	42
Perceptual Motor Performance	43
Straight and Level Warm-Up	43
Vertical S Trials	45
Correlations between Cognitive Mastery and Perceptual Motor Performance	58
Questionnaire	58
Discussion	64
References	72
Appendices	76

List of Tables

Table		Page
1	Program Evaluation Data, Tryout #2	31
2	Experimental Design	33
3	Correlations between Subject Characteristics and Perceptual Motor Performance Scores for the Straight and Level Warm-up Period	39
4	Correlations between Subject Characteristics and Perceptual Motor Scores (Means over Trials) for the Vertical S Trials Portion	40
5	Group Means for Cognitive Performance Measures	44
6	Mean Group Scores for Perceptual Motor Performance during Straight and Level Warm-up	46
7	Mean Group Scores for Perceptual Motor Performance over Six Vertical S Trials (Error Amplitude)	47
8	Mean Group Scores for Perceptual Motor Performance over Six Vertical S Trials (Hit Rate)	48
9	Mean Group Scores for Perceptual Motor Performance over Six Vertical S Trials (Percent Time on Criterion)	49
10	Mean Group Scores for Perceptual Motor Performance Averaged over Trials (All Descriptors)	50
11	Analysis of Variance: Error Amplitude E	51
12	Analysis of Variance: Hit Rate H	52
13	Analysis of Variance: Percent Time on Criterion T	53
14	t Tests for Groups A & B (Systematic Cues) versus Groups C & D (Current Cues) for Trials 1 and 2	54
15	Correlations between Cognitive Mastery and Perceptual Motor Performance on Six Trials	59
16	Correlations between Cognitive Mastery and Perceptual Motor Performance during the Warm-up and during the Trial Period	60
17	Subject Performance of Five Instructional Procedures	62
18	Mean Subject Ratings of the Experimental Treatments Received during Cognitive Pretraining	63

List of Figures

Figure		Page
1	Student Pilot Training Procedure	2
2	Closed Loop Control System: Pilot - Aircraft	37
3	Perceptual motor performance as measured by error amplitude (scores summed across variables) for three levels of cues over six trials (A x D interaction)	55
4	Perceptual motor performance as measured by hit rate (scores summed across variables) for three levels of cues over six trials (A x D interaction)	56
5	Perceptual motor performance as measured by percent time on criterion (scores summed across variables) for three levels of cues over six trials (A x D interaction)	57

List of Appendices

Appendix		Page
A	Summary and Raw Data on Subject Characteristics	75
B	Experimental Information for the Participating Subjects	81
C	Statement of Consent	83
D	Layout of the Experimental Facility	87
E	Structure of the Instructional Programs	89
F	Sample Program, Treatment A: Systematic Cues, Low Practice	92
G	Levels of Instructional Cues	145
H	Program Changes during Formative Phase	148
I	Experimentor - Subject Communications	150
J	Subject Master Sheet and Protocol Sheet (Examples)	153
K	Questionnaire	156
L	Scoring Algorithm and Keys	160

CUES AND PRACTICE IN FLYING TRAINING

Problem and Antecedents

Flight instruction in military, commercial or civil aviation is partly conducted in the air and partly on the ground. It is perfectly logical and immediately evident that the theoretical bases (as opposed to the applications) of such subjects as meteorology, aerodynamics and navigation are more economically taught on the ground. However, ground-based instruction does not stop with these "academic" components of a typical flying course. Even that part of flight instruction which deals directly with the practical control of an aircraft in flight (e.g., flying a barrel roll) is to a large part conducted in classrooms and briefing rooms on the ground. General consensus among flight instructors has it that for each hour in the air the student pilot should spend at the very least an equal amount of time preparing himself on the ground. The typical sequence of instructional events for a sortie in the aircraft is shown in Figure 1. This instructional procedure is based on the implicit and tacitly accepted assumption that some form and amount of cognitive training must precede hands-on in-flight training in an aircraft or a simulator if the sortie is to be successful and productive. Cognitive pretraining, in other words, is assumed to be a necessary although not a sufficient condition for the efficient acquisition of the complex perceptual-motor skills which are involved in flying an airplane.

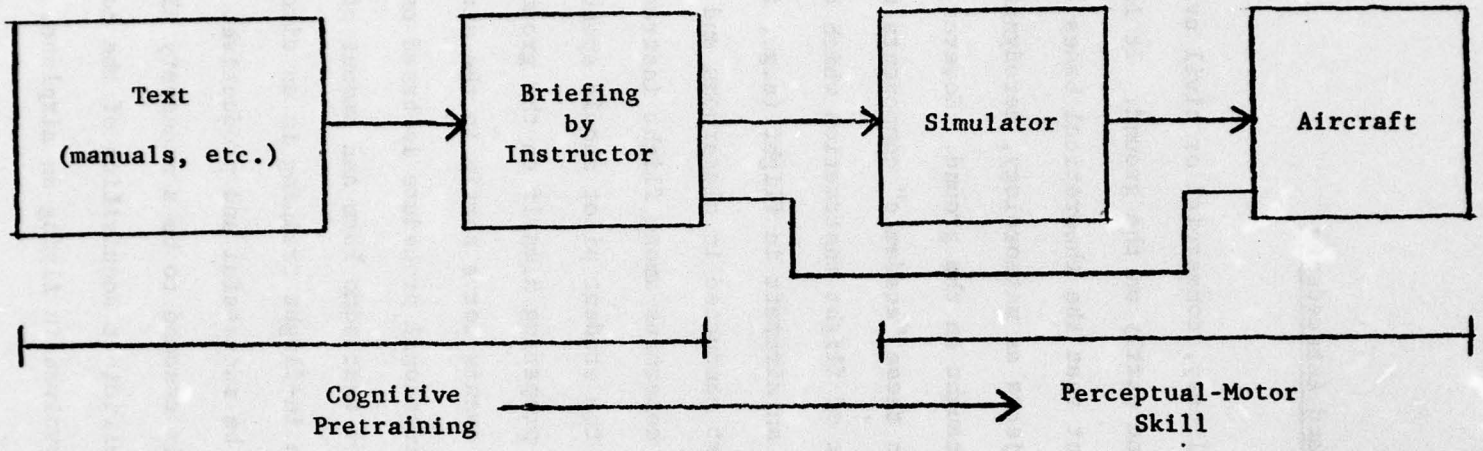


Figure 1: Student Pilot Training Procedure

Under current USAF regulations, cognitive pretraining is administered in the form of oral briefings which, as Figure 1 shows, are preceded by self-study of manual texts at the student's own discretion and pace. At least as far as USAF Undergraduate Pilot Training (UPT) is concerned, neither the manuals nor most of the briefings include any overt verbal practice and feedback. The current form of cognitive pretraining may, therefore--for all practical purposes--be characterized as a rote learning exercise or a one-way information dissemination from the teaching system (manual plus instructor) to the student.

The subject matter of cognitive pretraining consists essentially of verbal information on how to fly a given maneuver. This information is presented either in the form of a procedure or in the form of a technique or both. The distinction between the two is discussed in detail in Reiser, Brecke, and Gerlach (1972). A brief discussion of the most relevant characteristics of each is given below.

Procedures exist in many forms. From the filing of a flight plan to the walk-around inspection and back to taxiing, parking, and filling out the debriefing forms, the actions of a pilot are nearly always under the dictate of one procedure or another. Procedure is an official prescription, quasi-algorithmic in character, which consists of steps or chunks of information which can represent an elementary action. Other important features include a generally sequential structure, the relative ease with which an observer can determine whether or not a given procedure is being performed adequately, and its use as a standardization device. The procedures currently evident in the UPI curriculum generally deal with tasks of a relatively low level of complexity, i.e., with linear sequential tasks involving a finite set of discrete steps.

They may also deal with the target values of complex continuous control tasks, i.e., the concept "procedure" in the vernacular of the flight line has come to include those written parts of the subject matter for a specific flight maneuver which determine or describe desired performance characteristics.

Information beyond performance characteristics of complex control tasks is supplied to the learner in the form of "technique" rather than procedure.

A technique, in its pure form, is essentially heuristic while a procedure, in its pure form, is algorithmic. Heuristics are efficient strategies for the solution of many kinds of complex control problems. This is especially true if the heuristics have been refined by experience, i.e., by a more or less lengthy trial and error process. However, techniques as they are currently taught and generated in UPT present a problem. Transmitted by word of mouth from instructor pilot (IP) to student pilot (SP), they represent a highly idiosyncratic and jealously guarded body of flight line folklore. Each technique is considered to be the "personal property" of an IP and consequently technique as subject matter never really becomes part of the public domain. This leads to inefficiencies in the instructional process for a number of reasons:

(1) Techniques vary considerably in terms of efficiency and utility.

(2) The typical instructor pilot has not had enough experience either as a pilot or as a teacher to develop sound and teachable techniques. This is especially true of IP's who become instructors immediately after basic flight training.

(d) Due to the idiosyncratic, non-standardized nature of technique (as well as the high instructor pilot turnover rate) performance evaluation at best lacks empirical reliability.

(4) There may or may not be congruence between the technique an instructor transmits verbally and the technique he actually employs in a demonstration. This is a potential source of confusion for the student and may inhibit the effect of the verbal information intended to facilitate acquisition.

If we assume that verbal cognitive pretraining has facilitating effects on the subsequent acquisition of a complex perceptual-motor skill, and that these effects are directly related to qualitative or quantitative characteristics of the verbal information which is administered, then it is reasonable to hypothesize that that portion of training which consists of (private) technique could benefit from an intensive task-analytic effort aimed at a precise and explicit specification of all information relative to training for a given task.

The effect of one such parameter, the instructional cue (IC), has been discussed in a review by Roberts and Taylor (1972). In its simpliest form, an IC is that minimal informational stimulus which a learner needs in order to emit or acquire a previously unlearned behavior.

For example, in order to learn the skill of parking one's car parallel to and between two other cars, a learner requires a set of at least three instructional cues which may take a verbal form or a pictorial form or which may be given by using models or any combination. Whatever form is used, the cues must be successful in conveying the following:

(1) One has to start the maneuver from a position parallel to and alongside the first car.

(2) Back up while steering the front wheels away from the first car.

(3) Reverse the steering as soon as the driver's seat is even with the rear of the first car.

It is quite obvious that these cues can be worded much more succintly and clearly. It is also intuitively clear that cues which are well formulated will be more effective in helping a learner to acquire the desired behavior than cues which are less well formulated. This is, of course, as true for flying training as it is for driver education.

An analysis of the cue content of current manual texts and oral briefings in USAF undergraduate pilot training has shown that the instructional cues contained in these materials differ considerably from instructional cues which were developed by a systematic, semi-algorithmic procedure including a maneuver analysis based on a closed-loop control model. Systematically developed cues were less ambiguous and more specific, showed less variation in syntax and a more even coverage of the segments of a particular maneuver. The research question that follows is, in its simpliest form, "Can the learning of a complex perceptual motor skill be affected by systematically controlling the quality and the quantity of IC's in cognitive pretraining materials?"

A pilot experiment was conducted to test the differential effectiveness of currently operational cues and systematically developed cues against a group receiving the maneuver objective (as the two other groups) but no instructional cues whatsoever. Summative performance measures over all relevant flight parameters did not show significant differences between the treatment groups. Analysis of performance on separate flight parameters, however, revealed significant variations

between groups which were directly attributable to specific instructional cues. These results suggest that the treatments as administered were sufficiently powerful to produce learning of isolated cues but not powerful enough to produce mastery of whole sets of cues. One plausible explanation for this effect lies in the complete absence of overt cognitive practice in the treatments. It may, therefore, be assumed that the amount of practice during pretraining is another important factor influencing transfer to perceptual-motor skills. Increasing amounts of practice should lead to higher cognitive mastery and, therefore, to an increased availability of the cues during perceptual-motor performance.

The experiment described in this report was performed to investigate the effects of cognitive pretraining with two levels of instructional cues and two levels of practice on the acquisition of a complex perceptual motor skill, i.e., flying the maneuver Vertical S-A in a flight simulator.

Research Background

Theoretical Framework

Several researchers have suggested that learning a perceptual motor skill is a process which involves two to three more or less clearly identifiable stages. Fitts and Posner (1967) propose a three-stage model with an early or cognitive phase, an intermediate or associative phase and a final or autonomous phase. Adams (1971) assumes that the acquisition of a perceptual motor skill proceeds in two stages which he calls the Verbal-Motor State and Motor State, respectively. Posner and Keele (1973) present a two-stage model where the learner initially relies on conscious control and external feedback in closed-loop fashion and later shifts to "automatic" open-loop control independent of external feedback.

The common denominator for these three theoretical models is the concept of an initial stage of perceptual motor learning which is under verbal cognitive control (Adams, 1971, p. 131). During this phase, the learner tries to "understand" (Fitts, 1967, p. 11) the task to be performed and constructs his responses with the aid of verbal cognitive antecedents. Fitts and Posner (1967) speak of the development of an "executive program" (p. 11) during this phase, which "allows for the selection of an initial repertoire of subroutines from the available cues that have been developed previously" (ibid.). Miller, Galanter and Pribram (1966) are essentially in agreement with this position when they speak of the "verbalized strategies of a beginner" (p. 244) or of the "verbal plan" (ibid.) that the novice uses to guide his actions. During this initial phase of learning, the learner must rely on feedback which

originates primarily from external sources and which is processed in verbal form (Adams, 1971). The learner, therefore, operates initially in closed-loop control fashion, consciously adjusting his actions on the basis of external feedback (Posner and Keele, 1973).

A more concise formulation of the assumptions presented above, applied to the specific case of flying skill acquisition, was given in Brecke et al., 1974:

"(1) There are certain identifiable cognitive (or verbal) behaviors which are necessary, although not sufficient, conditions for learning a complex perceptual motor skill.

"(2) The student passes through a series of successive approximations beginning with a cognitive skill; gradually he adds a more-or-less unrefined motor response, and he terminates the process with the satisfactory integration of the cognitive behavior with a complex perceptual motor skill.

"(3) At the same time, the control of the student's behavior gradually shifts from stimuli extrinsic to his task in the aircraft or simulator (e.g., textual and oral instruction) to task-intrinsic stimuli (e.g., instruments, motion, sound, position of the aircraft with respect to selected referents)."

Given these assumptions it is possible to prescribe the gross features of an instructional procedure for the acquisition of flying skills, but it is not possible to infer details of form and content. If the initial phase of perceptual motor skill learning is indeed under verbal cognitive control, then initial instruction should be verbal cognitive as well, i.e., a cognitive pretraining phase should precede hands-on

perceptual motor skill training in the aircraft or simulator. Current instruction in UPT is subdivided and sequenced in precisely this way.

Specific desirable characteristics of cognitive pretraining in terms of form and content must be derived from other sources. The instructional materials currently used in UPT provide a useful starting point. Eight oral briefings on a specific maneuver, as well as the appropriate passages from two manual texts (AFM 51-37, ATCM 51-4) were analyzed by four independent judges (see Brecke et al., 1974). It was found that these materials contained almost exclusively verbal prescriptive rules specifying what the pilot should do and when he should do it. These verbal rules are essentially what Miller et al. (1966) have called "a learner's crutch" and what has been more rigorously defined as Instructional Cues (Gerlach et al., 1967; Roberts et al., 1972). For any given behavioral objective exists an instructional cue or a set of instructional cues, which represents that information (in verbal or non-verbal form) which a learner needs in order to acquire or emit the behavior specified by the objective.

The assumption that cognitive pretraining materials which consist primarily of instructional cues should be effective mediating agents of perceptual motor skills is both intuitively appealing as well as theoretically defendable. From the viewpoint of information theory, facilitating effects of cognitively acquired cues may be expected if the learner can utilize them to reduce the information processing load of the perceptual motor task (Shannon, 1948; Weltner, 1969). This will always be the case if (a) the cue is learned to mastery and (b) if the instructional cue is so designed that it facilitates the choice among perceptual cues for the learner. An associationistic explanation would predict

facilitation if the instructional cues were of such relevance and specificity as to elicit fewer competing responses during the acquisition and/or performance of a skill (Noble, Alcock & Frye).

The rather general properties of instructional cues specified by these theoretical considerations are still an insufficient basis for instructional design. The problem is at this point (1) What are the specific characteristics that instructional cues should have in order to be maximally facilitative and (2) Is it possible to develop an objective procedure for the design of maximally effective cues?

Answers to these questions were sought by employing control systems theory to develop a model of the pilot's information processing task. This approach to perceptual motor behavior originated from the writings of Craik (1948) and Wiener (1948). These writers were the first theoreticians to apply the principle of servo control from the engineering sciences to human physiology and psychology. Wiener's Cybernetics in particular presented a coherent theoretical framework which was argued with mathematical precision and which is today a serious rival to the various S-R approaches. A number of writers (Welford, 1967; Adams, 1971; Schmidt & Schmidt, 1966) in the field have presented cogent arguments why the cybernetic approach should really replace any S-R theorizing.

Some idea of the flexibility and power of the servo control model may be conveyed by the range of its applications. Fairbanks (1954) has described the speech mechanism as a servo system; the Russians Anokhin (1969) and Sokolov (1969) both deal with phenomena within the central nervous system and Frank (1969) has applied the model to goal directed human activity in general and to the interaction of teacher and learner

in particular. Frank as well as Paillard (1960), Chase (1965a, 1965b), Gibbs (1970) and Adams (1971) all have dealt with perceptual motor activity and have suggested models of varying complexity. The model developed by Frank represents the most general and parsimonious work and was, therefore, used (Brecke et al., 1972) to develop a model of the interactive system pilot-aircraft (see Figure 2). This model is compatible with the writings of Fitts (1951, 1954, 1964, 1967) as well as those of. Posner and Keele (1973).

It is clear from this model that the pilot has to deal with three classes of information (Brecke et al., 1972, pp. 6-8):

(1) Information describing desired airplane performance

(2) Information describing the control activations which determine airplane performance

(3) Information describing current system performance.

It is possible to compile these three classes of information for a given maneuver by using an objective task analysis procedure which has been called maneuver analysis. The result of a maneuver analysis is a complete information base. This information base represents the content or subject matter that instructional cues for a given maneuver must deal with. An instructional designer and subject matter expert team can then use this information base to design instructional cues by asking a set of standard questions (Gerlach et al., 1972). The cues which have been generated in this maneuver are subsequently checked against a list of criteria (see Table 1) which has been developed on the basis of the control systems model (Brecke et al., 1974).

To recapitulate: the theoretical arguments presented so far result in a set of assumptions concerning the design of instructional procedures

Table 1

Program Evaluation Data

Tryout #2

Groups	n	Variables: Time through program[a]	Errors on posttest[b]	Time through posttest[a]
Systematic Cues				
Low Practice	2	26.0	7.5	10.0
High Practice	2	37.0	8.5	7.5
Current Cues				
Low Practice	2	26.5	17.5	12.5
High Practice	2	37.5	7.0	10.0

[a] in minutes

[b] total number of items: 27

and materials for the teaching of perceptual motor skills. These assumptions are:

(1) The first stage of perceptual motor skill acquisition is under verbal cognitive control. Cognitive pretraining should, therefore, precede perceptual motor training.

(2) Cognitive pretraining may be described in terms of the variable Instructional Cues.

(3) The characteristics of Instructional Cues which are highly effective as mediators of perceptual motor skills can be specified and cues of this nature can be developed on the basis of an objective procedure based on control systems theory.

The assumptions (1) and (2) can be supported by empirical research dealing with mental practice, verbal pretraining and the effects of differential instructions. The third assumption is the basic assumption to be tested in this study. The remainder of this section is devoted to a review of the literature concerning the first two assumptions and to a statement of the specific hypotheses which were investigated.

Related Research

Mental Practice. One source of evidence to the effect that cognitive factors may be important determinants of perceptual motor learning comes from studies dealing with the effects of mental practice. Mental or cognitive practice or rehearsal (the terms are used interchangeably) refers to the practice of a physical activity without muscular movement, i.e., the learner imagines himself going through a perceptual motor task without

executing any of the movements associated with the task. Generally, studies of this type have compared gain scores of Ss which had been subjected to training conditions which involved either mental practice or physical practice or no practice.

Richardson (1967) in a review of this area of research, examined 25 studies which had been done over the last 30 years prior to 1965. He reports (p. 102):

"1. Despite a variety of methodological inadequacies the trend of most studies indicates that MP (mental practice. Author.) procedures are associated with improved performance on the task. Statistically significant positive findings were obtained in 11 studies - (). Seven further studies show a positive trend - (). Three studies report negative findings - ()".

Of particular interest with regard to the first assumption stated above (p. 13), are two conflicting studies mentioned by Richardson which used combinations of physical and mental practice. Trussell (1952) found that six days of mental practice (5 min. each day) followed by 14 days of physical practice resulted in the highest gain scores. The second best treatment condition was physical practice alone; 14 days of mental practice (5 min. daily) followed by 6 days of physical practice ranked third and the mental practice only condition ranked forth. These results clearly support a cognitive pretraining procedure. Ammons (1951) on the other hand found that a 2-min. mental practice session prior to a 12-min. physical practice session did not result in significantly higher improvements than seven other combinations. It may be argued that the 2-min. mental practice interval was too short to

result in any cognitive learning and that it, therefore, may have led to interference rather than to facilitation.

Relatively few mental practice studies have been reported after 1965. Shick (1970) used two tasks, serving a volleyball and volleying against a wall. She found that mental practice resulted in significant improvements over no practice on the serving task but not on the volleying task. Her study did not include a physical practice only condition. Hall (1971) used a rotary pursuit task and found physical practice and observational practice superior to mental practice. The latter group did not differ from a no practice group. He found some indication supporting an earlier finding by Clark (1960) that success of mental practice may depend on the degree to which Ss are familiar with the task. Rawlings, Rawlings, Chen and Yilk (1972) in two very carefully controlled studies also used rotary pursuit tracking, a task which may be considered unfamiliar to most Ss. They demonstrated clearly that mental rehearsal facilitates the acquisition of a rotary pursuit tracking skill and provided evidence that a combination of mental practice and physical practice may be the most efficient technique for learning a perceptual motor skill.

The research reviewed so far permits the general conclusion that perceptual motor learning may be partly a function of cognitive variables, especially during the earlier stages. More specific conclusions do not appear warranted since the confounding of such variables as the nature and complexity of the task, the effect of experimental instructions, the amount of time for each condition, and the sequencing of practice conditions do not allow direct comparisons. Perhaps the most serious shortcoming of this research is the fact that experimental control over the

mental practice condition appears to have been very weak. Extreme caution should, therefore, be exercised in generalizing from these findings to flying training. Another reason for caution are differences in the perceptual motor task. The tasks which have been employed in mental practice research were either ballistic open-loop tasks (e.g., basketball throwing) and, therefore, fundamentally different from the closed-loop flying task, or they were closed-loop tasks (rotary pursuit) which were considerably less complex than any flying task. Rawlings et al. (1972) characterize the rotary pursuit task as one which "does not have a particularly significant cognitive component." This characterization certainly does not apply to any flying task where a variety of numerical stimuli from the instrument panel require constant and substantial cognitive information processing. It is, therefore, conceivable that some form of mental practice may have very strong facilitating effects on perceptual motor skills which have significant cognitive components, such as flying. This conclusion is supported by a recent study (Prather, 1973) which used a flying skill (landing the T-37 aircraft). Prather achieved a considerable amount of control over the mental rehearsal condition by using four tape recordings with successively fewer verbal prompts. Ss who had engaged in prompted mental practice received significantly higher ratings from instructors on their landings.

Verbal Pretraining

Studies more specifically aimed at the investigation of particular variables which determine cognitive facilitation of perceptual motor skill acquisition have investigated transfer effects from various forms of verbal discrimination pretraining. The experimental tasks used in

this line of research consist of the presentation of discrete static stimulus configurations (such as a single light or a set of lights) to which S has to make a single ballistic response (i.e., moving a lever or a switch). The pretraining treatments consist in learning pairs of stimulus-response associations where either the stimuli or the responses or both are replaced by various types of relevant or irrelevant (verbal) substitutes as illustrated in Table 2.

Of particular interest to the present study is the type of pretraining which has been labelled Relevant S-R pretraining (McAllister, 1953). Ss subjected to this treatment condition learn to pair a relevant stimulus with a relevant response. This means for example that they learn to say "right two" (meaning: Switch #2 on the right) if presented with the verbal stimulus substituted "top green" which stands for the top green light of a display (Baker & Wylie, 1950). Stimulus-response combinations of this type are essentially atomic rules (Scandura, 1968) or very concise instructional cues. These cues are specific; they are by definition relevant and--if learned to any degree--will certainly reduce the subjective information of the perceptual field in the criterion task.

McAllister administered five variations of Relevant S-R pretraining and compared these with Irrelevant and Relevant-S pretraining. All Relevant S-R conditions resulted in significantly fewer errors on the criterion task (Star discriminator). Battig (1956) used a finger positioning apparatus and found Relevant S-R pretraining more facilitative than Relevant-S pretraining and a control condition which had no pretraining at all. These findings are in agreement with Baker and Wylie (1950), Cantor (1955) and Goss and Greenfeld (1958) who all found significant facilitation of subsequent perceptual motor performance for groups

receiving relevant S-R pretraining, i.e., a pretraining incorporating instructional cues.

Especially interesting is the study by McAllister (1953). The degree of facilitation accruing from the Relevant S-R pretraining was found to be dependent on the type of verbal response substitute. The more closely the latter resembled a description of the movement to be made, the higher was the positive transfer to the perceptual motor task. This evidence suggests that "relevant" cues may differ greatly in their facilitating effects depending on the information processing they receive. The more familiar the concepts are which are included in the cues the greater will be any facilitative effect.

A second significant finding arising out of this body of research is the fact that Ss' performance on the criterion task is not only a function of the characteristics of instructional cues but also of the degree to which these cues have been practiced and, thus, mastered in cognitive terms. In other words, not only what S learns, but also how well he learns it, is important.

Baker and Wylie (1950), in a verbal Relevant S-R pretraining experiment using a discrimination-reaction task gave 8 and 24 verbal practice trials and found significant amounts of transfer after 24 practice trials both in terms of fewer errors and shorter reaction times but no transfer after 8 practice trials. Holton and Goss (1956) found the amount of perceptual motor facilitation to be increasing with increasing number of trials during pretraining. Goss and Greenfeld (1958) pretrained Ss to 7 different criteria of mastery and found the amount of transfer to be a direct function of the master levels attained during pretraining.

The findings of verbal pretraining research which have been presented lend strong support to the assumption that cognitive pretraining materials should incorporate instructional cues and that these cues must be practiced to a minimal degree of mastery. There are even some indications as to the specific characteristics of maximally effective cues. These results are judged to be considerably more dependable than the results of mental practice studies because of the superior experimental control which is possible with this paradigm.

Differential Instructions

The concept of cognitive pretraining also encompasses any form of instructions or directions given to Ss prior to their performance of an experimental task. Most experimentation on perceptual motor skill learning involves the use of apparatus generally unfamiliar to Ss. In order to insure proper use of the "hardware," Ss, therefore, receive what is commonly referred to as "experimental instructions." Relatively few researchers have concerned themselves with the effects of these instructions as an independent variable.

Renshaw and Postle (1928) investigated rotary pursuit tracking under three types of instruction. One group received instruction describing merely the task objective. A second group received the task objective and was urged to analyze the task (in writing) between sittings on consecutive days. The third group received, before each sitting, the task objective and carefully prepared instructions "which described in detail all the known facts about the nature of the task, its difficulties, the best methods of operation, etc. "Ss in the latter condition performed significantly worse over 25 trials on 5 days than either the

'Objective Only' or the 'Analyzer' groups." Noble, Alcock and Farese (1958) used a task requiring series of discrete motor responses to series of discrete stimulus presentations with two levels of specificity of instructions. Ss receiving instruction containing the task objective, instructional cues on how to attain it, and verbal examples exhibited a significantly higher probability of a correct response than Ss who received the task objective only. Noble, Alcock and Frye (1959) corroborated this finding with a discrimination reaction time task. Ss receiving specific instructions and six practice trials had a significantly shorter reaction time R_t over 160 trials than Ss receiving the task objective only and no practice trials. The findings of Noble and Alcock (1958, 1959) are essentially in agreement with the findings of McFann (1953), who observed greater facilitation and less interference on relearning when Ss received specific information as to how an intermediate task differed from the original task.

The findings of Renshaw and Noble et al. do not necessarily contradict each other. Ss in the specific instruction condition of Renshaw's study received not only specific instructions but also a large amount of information which was irrelevant with respect to the actual performance of the task. It may be surmised that these irrelevant instructions had the same effect as non-specific instructions in Noble's experiment: they may have led to the elicitation of competing responses. Translated into the vocabulary of information theory the interpretation would be that irrelevant or non-specific instructions increase, instead of reduce, task information. However, any attempt to interpret these studies from the vantage point of some unifying theory is greatly hampered by the lack

of a consistent operational definition of the variable "Instructions." The differences in the tasks employed compound this difficulty.

Summary

Theoretical considerations as well as an analysis of current instructional materials led to a set of assumptions concerning the design of procedures and materials for the teaching of perceptual motor skills. Briefly stated these assumptions are:

(1) A cognitive pretraining phase should precede perceptual motor training.

(2) Cognitive pretraining can be defined in terms of the variable Instructional Cue.

(3) Instructional Cues can be operationally defined and developed. Experimental research concerned with mental practice, verbal pretraining and differential instructions clearly supports the first two assumptions. It also furnishes some indication that the third assumption is tenable and which directions an operational definition would have to follow.

On the basis of this theoretical and empirical background it was possible to define two levels of the variable Instructional Cue. The two levels were tested experimentally for their effectiveness as cognitive mediators of perceptual motor behavior. The results of this experiment as well as the findings of verbal pretraining research suggest that the facilitative effect of cognitive pretraining is at least partially a function of the degree of cognitive mastery (M) attained by the learner as a result of pretraining. Cognitive mastery in turn is dependent on the type of instructional cue (IC) and on the amount of practice (P) →

administered during pretraining. Pretraining on relevant and logically coherent cues appears to result in higher levels of cognitive mastery as well as perceptual motor performance (PM) than pretraining on irrelevant and logically incoherent cues. The amount of cognitive practice incorporated in pretraining also appears to relate directly to cognitive mastery as well as perceptual motor performance. If, therefore, either of these variables influence cognitive mastery and/or perceptual motor performance, it would be reasonable to expect interactive effects.

Variables and Hypotheses

The present study was designed to investigate these relationships using the following operational definitions and hypotheses:

Independent Variables

(1) Type of Instructional Cue (IC)

Levels:

(a) *CC: Currently operational cues*

(b) SC: Systematically developed cues

The two sets of cues are based on those used during the pilot study.

(2) Amount of Practice (P)

Levels:

(a) Low: 1 mastery item for each of six subsets of cues

(b) High: 3 (identical) mastery items for each of six subsets of cues.

Dependent Variables

1 Cognitive Mastery (M): Number of errors on a written posttest administered immediately after pretraining.

2 Perceptual-Motor Performance (PM): Mean number of flight parameters within criterion limits per unit of time.

Hypotheses

A. Effects of Instructional Cues and Practice on Cognitive Mastery

H_1: Pretraining incorporating systematically developed cues will result in higher cognitive mastery than pretraining incorporating currently operational cues.

H_2: Pretraining incorporating a high level of practice will result in higher cognitive mastery than pretraining with a low level of practice.

H_3: There will be a significant interaction effect on cognitive mastery for two levels of practice and two levels of instructional cues.

B. Effects of Instructional Cues and Practice on Perceptual-Motor Performance

H_4: Pretraining incorporating systematically developed cues will result in better perceptual motor performance than pretraining incorporating currently operational cues.

H_5: Pretraining incorporating a high level of practice will result in better perceptual-motor performance than pretraining with a low level of practice.

H_6: There will be a significant interaction effect on perceptual-motor performance for two levels of practice and two levels of instructional cues.

C. Relationship between cognitive mastery and perceptual-motor performance

H_7: There will be a significant positive correlation between cognitive mastery and perceptual-motor performance.

Method

Subjects

Student pilots from two flights of the USAF training installation at Williams AFB constituted the available subject pool. A sample of N = 45 Ss were selected from this pool on the basis of least flight experience prior to UPT (limit: 250 hours). Ss were randomly assigned from an alphabetized list to one of five groups (four experimental groups, one independent control group).

The sample was diminished by a total of six Ss before and during the experiment. Three Ss were eliminated prior to experimentation due to scheduling problems (2) and sickness (1). One S did not understand experimental instructions and two Ss could not be processed due to equipment breakdowns. The final distribution of the remaining N = 39 Ss was n = 8 for groups A through D and n = 5 for group E.

Three subject characteristics were assumed to be related to performance in the simulator:

(1) number of hours in the simulator

(2) number of hours in the airplane

(3) number of hours of training prior to UPT.

Data on these and other subject characteristics are listed in Appendix A. These data show that the groups were equivalent with respect to the first two criteria mentioned above as well as with respect to age. The groups were significantly different with respect to the third criterion: number of hours of training prior to UPT. The potential impact of differences on this criterion is difficult to estimate since this variable is confounded with others, such as the type and the recency of prior

training. It was, therefore, decided not to match the groups on this variable, but to use covariance procedures if indicated by the data.

The use of human subjects in this study was in accordance with policies and regulations published by the Dissertation Committee (p. 32) at Arizona State University. All Ss were informed of the procedure (Appendix B) and signed their consent prior to experimentation (Appendix C).

Apparatus

A flight simulator (A/F37A/T4-G SINGER-LINK) for the Cessna T-37A was used for the performance of the flight task.

An Incre-Logger Model 4409 Data Recorder using precision cassette tapes was connected to the T4-G computer, taping the output voltages for the airspeed indicator, the attitude indicator, the vertical velocity indicator, the altimeter and the tachometers. The Incre-Logger was set to scan all six channels at a rate of one scan per second.

Pretraining was administered in an isolated study carrel located in the same room as the simulator (Appendix D).

Treatment Materials

Treatments for all four experimental groups consisted in linear self-instructional programs on the maneuver Vertical S-A developed on the basis of materials used in prior experimentation. The programs were identical in structure (Appendix E), i.e., all programs had the same introductory section on the maneuver, the same division by maneuver segments and equivalent mastery items requiring an overt (pencil) response. Feedback is provided after each response. The programs differ only in

the sets of instructional ues per segment and in the number of mastery items per segment. Each program includes a posttest at the end. The posttest is identical for all four versions. A sample program can be found in Appendix F.

The program for the control group had the same introductory section as the four experimental programs. This section was followed by blank pages on which the students were to write in their own words the steps they would follow in executing the maneuver.

The development of the two levels of each of the two independent variables is described below.

Levels of Instruction Cue. The levels of this variable were developed on the basis of extensive analytical work. Experimentation contrasting the transfer effects of either level demonstrated the validity of the operational definitions and clearly established the power of the variable as well as the possibilities for its systematic manipulation.

The set of Currently Operational Cues was developed from current instructional materials. Briefings on the Vertical S-A maneuver given by eight different Instructor Pilots were covertly recorded in the normal instructional environment, i.e., on the flight line. Transcriptions of all eight briefings were then distributed to four judges who independently identified the instructional cues contained in the briefings. Even though the judges differed greatly in terms of subject-matter knowledge, they agreed on better than 80% of the cues identified. A stratified random sample drawn from the pool of cues thus identified constituted the set of Current Operational Cues.

The set of Systematically Developed Cues was developed with the aid of a maneuver analysis (Brecke et al, 1972; Gerlach et al, 1972). This analysis specifies three classes of information for every maneuver segment: Aircraft Parameters, Control Parameters and Information Sources. The procedure is replicable and generalizable to other maneuvers. Cues are then generated by applying a quasi-algorithmic procedure to the comprehensive and precise information base generated by the analysis. Four sets of cues generated independently by four different instructional design experts were highly consistent in terms of cue content and somewhat less consistent in terms of syntax. The most concise formulations were combined into one list which was then subjected to four revision cycles, during actual maneuver performance were anlyzed and incorporated.

The sets of currently operational cues and systematically developed cues (Appendix G) are numerically equivalent. They represent the subject matter core for the instructional programs.

Levels of Practice. The two levels represent both the minimal and the maximal amount of practice which appear to be feasible with the type of programmed instructions (P.I.) selected. During the formative stages of the program development it became apparent that at least one mastery item per segment set was necessary to produce posttest scores in the neighborhood of 50%. More than three identical mastery items were not feasible due to time constraints.

Program Development and Validation. The programs were developed on the basis of the following objective:

"The learner can name in writing the set of cues for the instructional maneuver 'Vertical S-A' in correct order."

Enroute objectives called for the same "naming in order" response but for the subsets of cues of the individual maneuver segments.

Objectives calling for learners to apply the cues to such stimuli as a pictorial or photographic representation of the instrument panel would have required different practice items for different levels of IC. Since the inclusion of non-equivalent practice items might have represented an uncontrolled source of variance it was decided to restrict the program objectives to naming behaviors only.

The programs were duplicated and assembled in a spiral-bound booklet (8.5 x 11 inches) and then subjected to three cycles of test and revision.

The first formative evaluation was conducted with the program for the Systematic Cues/Low Practice condition (Treatment A). One S participated in this exploratory trial which was conducted as a frame-by-frame discussion. S was naive with respect to the subject matter (especially the aeronautical terminology), but non-naive with respect to the design of instruction. No posttest was administered. A number of inconsistencies of expression and other technical shortcomings were discovered. S commented explicitly on the lack of feedback. Program revisions after this initial tryout were restricted to the removal of the technical shortcomings only.

The second formative evaluation was conducted with the same program version using two Ss from the AFROTC unit at Arizona State University. Both of these subjects had gone through the Flight Indoctrination Program offered by ROTC and were familiar with the specialized terminology. Both Ss were naive with respect to instructional design. Ss were

instructed to work through the programs at their own "comfortable" rate. No aid was given. During the test both Ss were under constant observation. No posttest was administered. Ss finished the program in 42 and 51 minutes. Both Ss showed a very positive affective response to the program as a whole and made unsolicited comments on the usefulness of the illustrations. Both Ss suggested that feedback be added.

The programs were revised to include feedback (KCR) after each learner response. A posttest was added at the end of each program. A complete list of the changes resulting from the first two program evaluations is found in Appendix H.

A summative evaluation test was conducted with all four program versions using a total of eight ROTC students: two in each condition. These Ss were very similar to the target population (UPT students) with respect to age and flight experience. Ss were instructed to work at their own rate and to take the posttest immediately upon completion of the program. The results of this evaluation (Table 1) corresponded to expected hypothetical outcomes. Ss receiving Current Operational Cues required more practice to reach the same performance level (number of errors on the posttest) as Ss receiving Systematically Developed Cues. The times for program completion were judged to be within acceptable limits.

The programs still had one serious shortcoming. The paper was so thin that it was possible to see the KCR on the next page. The problem was solved by inserting a page of blue paper between each response frame and the following feedback frame (omitted in the sample program in Appendix E).

Design

A 2 x 2 factorial posttest-only design with an independent control group was employed. The design is illustrated in Table 2. A pretest on the perceptual motor task used in the experiment was not possible due to logistical constraints.

This design permits testing of all listed hypotheses, but it does not allow direct evaluation of the effects of Instructional Cues alone. On the basis of prior experimentation, it was considered impossible to produce sufficient learning of the cues without some form and amount of overt cognitive practice.

This design probably resulted in some posttest-treatment interaction even though the learners received no feedback from the posttest. In the judgment of the writers, the threat to external validity resulting from the posttest is outweighed by the insights gained from a test of the relationship between cognitive mastery and perceptual motor performance.

Procedure

Experimentation was conducted during the period from March 6 to March 18, 1974, at the Human Resources Laboratory at Williams AFB. Ss were normally scheduled one hour apart. An average time of one hour and 20 minutes was required to process one S through the experiment, so that there were usually two Ss present: one in the simulator and one in the study carrel. One experimentor (E) could easily direct the flow of Ss and monitor the data collection.

Upon reporting to E the subject went through the following procedure:

(1) Cognitive pretraining. E placed S in the study carrel and instructed S to first read the sheet entitled "for Your Information"

Table 2: Experimental Design

Instructional Cues	Practice: Low	Practice: High	Practice: None
Systematic	A	B	
Current	C	D	
None			E (Independent Control)

(Appendix B), then sign his consent (Appendix C) and then start working through the program. S was told to mark the time he began to work on the program and the time he finished the program.

(2) Cognitive posttest. S took the cognitive posttest immediately upon completion of the program. S again had to mark the time when he finished the posttest.

(3) Perceptual motor training. Immediately upon completion of the cognitive posttest S walked over to the simulator and handed his programmed booklet with the posttest to E. E then checked whether the times had been marked as instructed and had S take a seat in the simulator (left seat). The simulator was in "FREEZE" condition at 15,000 feet, 160 knots, 360° and 81% RPM. After a standard headset communication check, S was told (in a standard conversation) to get comfortable, to adjust the rudder pedals and to use a light touch on the stick (Appendix I). The hood was then lowered and locked to reduce environmental interference and S assumed control of the simulator after E had released the FREEZE switch.

E started the recorder and S then flew straight and level for five minutes. After five minutes, S started the first Vertical S-A maneuver. Upon finishing the maneuver S flew straight and level for one minute and then started his next Vertical S, repeating this sequence until six maneuvers were completed. The recorder was left on throughout this period up to the completion of the last maneuver. E also kept a Subject Master Sheet and a Protocol Sheet during this time (Appendix J).

(4) After the sixth trial, the simulator was again put into the "FREEZE" condition. S left the simulator and answered a brief questionnaire (Appendix K) designed to obtain some indication of S's retention

of instructional cues as well as to elicit some comment and critique of the pretraining procedures and materials. Upon completion of the questionnaire, S was dismissed.

Data Collection and Analysis

Cognitive mastery M was operationally defined as the number of errors on the cognitive posttest. This test was scored independently by two judges using an algorithm in conjunction with a key for each of the the two levels of cues (Appendix L). This procedure ensured a highly objective measure free of any scorer bias. The judges arrived at the same scores in each and every case.

Perceptual motor performance indexes were computed on the basis of six measures:

(1) Airspeed

(2) Heading

(3) Altitude

(4) Vertical Velocity

(5) Pitch Attitude

(6) Power

These measures were obtained automatically at one second intervals by taping the analog input to the appropriate instruments. The recorder (see p. 25) converted the analog voltages to digital signals and recorded these on precision cassette tape. This data collection procedure resulted in an extremely precise and complete performance record as long as the equipment was functioning properly. Equipment malfunctions were encountered on some of the subject records. These malfunctions always resulted in an intermittent failure to record data. The failure periods

lasted an average of 3 scans. In order to compensate for this loss of data, an interpolation algorithm was developed and validated using complete data sets as testing criterion. All of the missing data could thus be recovered with a very high degree of reliability. A typical trial record before and after the data recovery procedure is shown in Figure 2.

The performance records obtained in this manner provided the raw data for the computation of three different indices of overall performance quality:

(1) Time on criteria: Percent of total trial time S was within criterion limits averaged over all six measures.

(2) Hit Rate: Average number of criteria on which S was within limits at any point during a maneuver.

(3) Error Amplitude: Inverse Hit Rate combined with the average error magnitude.

The computation of these indices as well as the automatic recording of the complete performance history as outlined above were outcomes of prior work on the research project of which this report is a part. They are described in complete detail in Shipley, Gerlach and Brecke, 1974.

The same is true for the data analysis procedures which were employed in this study. With the exception of the data on cognitive mastery M and subject characteristics, all data were processed and analyzed by using MANOVA procedures and computer programs which had been developed prior to this study. A complete description and evaluation of these procedures is also found in Shipley et al, 1974.

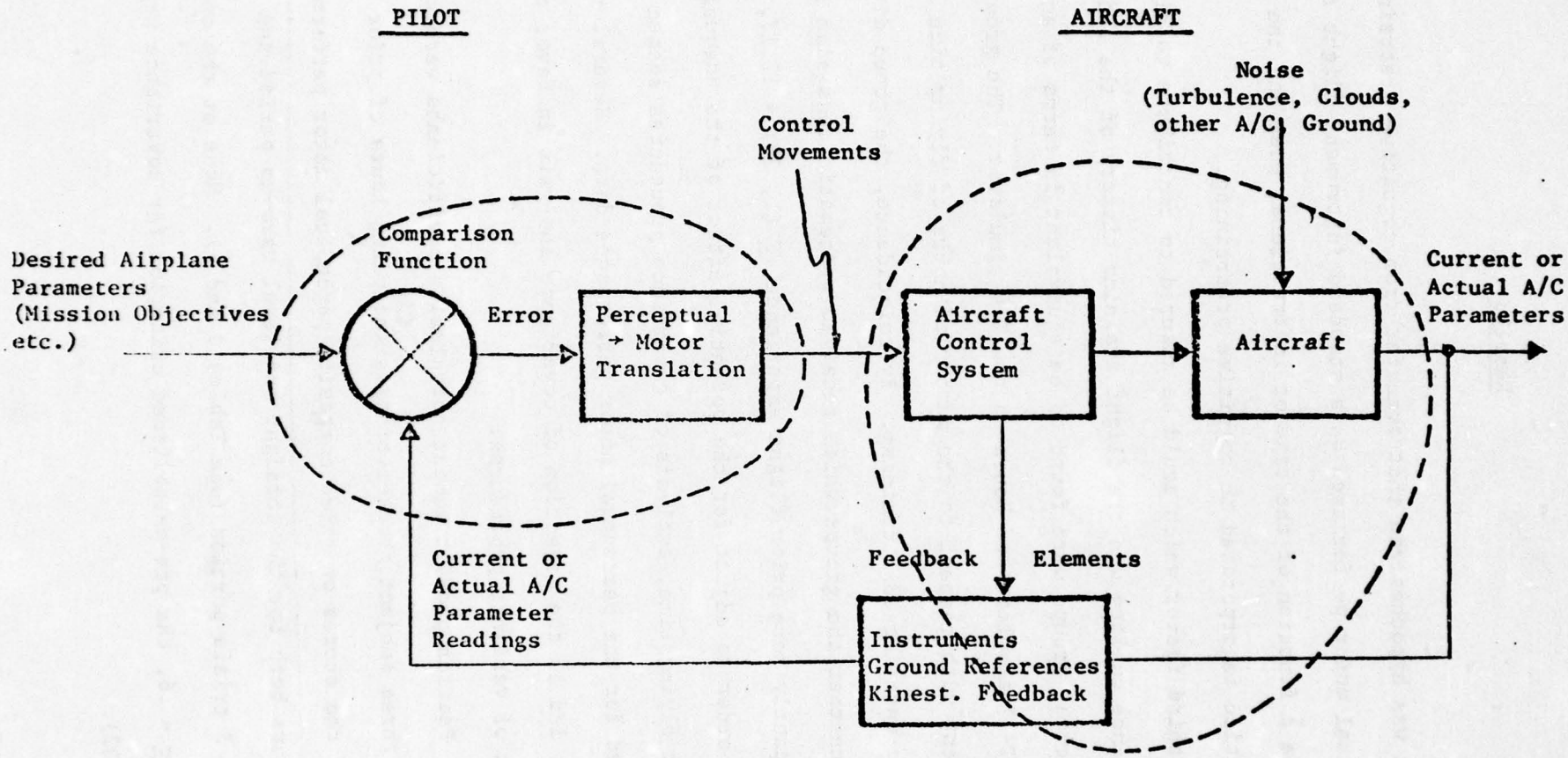


Figure 2: Closed Loop Control System: Pilot - Aircraft

Results

It was hypothesized that transfer from cognitive pretraining to perceptual motor performance on a standard instrument flight task would be a function of the type of instructional cues and the amount of practice incorporated in cognitive pretraining.

A third factor which could be assumed to contribute to differential performance quality was the flight training history of the subjects. The experimental groups were found to be equivalent in terms of age, hours on the T-37 airplane and hours on the T-4 simulator. The groups were not equivalent with respect to the number of hours of flying time logged prior to entering USAF training. By coincidence, the group differences were such that the groups which received systematic cues also had significantly more prior flight experience, F (1, 28) = 12.17, $p < .01$.

In order to adjust for the potential effect of the unequal hours of prior flying time, analysis of covariance procedures seemed to be indicated for the perceptual motor performance data. Several reasons, however, led to the rejection of covariance analysis in favor of normal analysis of variance procedures.

1. Pearson product moment correlation coefficients were computed between three subject characteristics including hours of prior flying time and the scores on three composite perceptual motor performance descriptors both for the straight and level warm-up period and for the Vertical S trials portion (see Tables 3 and 4). None of the correlations reached $r = .6$, the pre-established criterion for covariance procedures (see p. 32).

Table 3

Correlations between Subject Characteristics and Perceptual Motor Performance Scores for the Straight and Level Warm-up Period

Subject Characteristics	Performance descriptors		
	Error amplitude	Hit rate	Percent time on criterion
Hours of prior flying time	.335*	-.183	-.192
Hours on T-37 (airplane)	.117	.057	.032
Hours on T-4 (simulator)	-.231	.231	.128

*$p < .05$

Table 4

Correlations between Subject Characteristics and Perceptual Motor Scores (Means over Trials) for the Vertical S Trials Portion

Subject characteristics	Performance descriptors		
	Error amplitude	Hit rate	Percent time on criterion
Hours of prior flying time	-.023	-.072	.011
Hours on T-37 (airplane)	-.204	.089	.067
Hours on T-4 (simulator)	-.422*	.256	.372*

*$p < .05$

2. The one significant correlation for error amplitude during the straight and level portion must be considered inconclusive since none of the other composite performance descriptors show correlations which come close to significance ($r \geq .268$). The correlations with the average trial performance scores are lower yet (Table 5), and in this portion of the simulator performance, error amplitude does not correlate at all with hours of prior flying time.

3. The perceptual motor performance data showed heterogeneous group variances. While it is known that the F-test of an analysis of variance is relatively robust with respect to violations of the assumption of homogeneity of variance, it has been shown (Elashoff, 1969) that analysis of covariance procedures are far less robust against violations of this assumption.

4. The highest correlations were found for hours on the T-4 simulator and perceptual motor performance both for the warm-up and for the trials portion. Hours on the T-4 would therefore be a more reasonable covariate than hours of prior flying time. The groups were, however, equivalent with respect to this characteristic.

5. Hours of prior flying time is a very incomplete indicator of pilot experience since it takes into account neither the type of flight training (private, commercial, military, single or multi-engine) nor the recency of such training. The potential effects of 50 hours of helicopter training two years before the experiment cannot be equated with 50 hours of military single engine light plane training one-half year before the experiment.

The reasons cited above were considered ample justification for the choice of normal analysis of variance procedures. In all analyses, the 2 x 2 design was analyzed first. Then, comparisons between the independent control group and the four experimental groups were performed where appropriate, using Dunnett's Test (Myers, 1966, p. 337).

Cognitive Performance

Cognitive mastery as measured by percent correct scores on the immediate posttest showed a significant instructional cues effect, F (1, 28) = 8.24, $p < .01$. Subjects who had received systematic cues achieved higher scores on the immediate posttest than those who had received current cues. Practice effects were not significant; neither were the interactions.

Measures of time through program and time through posttest showed significant effects for practice, but not for instructional cues. Subjects who had received a high amount of practice spent, of course, more time working through the program, F (1, 28) = 39.65, $p < .0001$, however, they spent significantly less time in completing the posttest, F (1, 28) = 6.04, $p < .05$. Interactions were not significant.

Program efficiency, measured as the quotient between percent correct on the posttest and time through program in minutes, showed a significant practice effect, F (1, 28) = 15.24, $p < .001$. Subjects in the low practice conditions made more correct responses on the posttest per minute of invested learning time than subjects in the high practice conditions.

Group means for cognitive performance measures are shown in Table 5. Raw data and analysis of variance tables are included in Appendix P.

Perceptual Motor Performance

It will be recalled that perceptual motor performance was measured by recording the actual indications of six cockpit instruments. The altitude record was later found to be too noisy and was dropped from further analysis. From the raw data on the remaining five variables, three different types of derived scores, called performance descriptors, were computed. This resulted in 15 single variable performance descriptors which could be summed across variables into the three composite performance descriptors T_{Σ}, H_{Σ} and E_{Σ} (see Table 3, p. 49).

Analysis of variance procedures were applied to all 15 single variable scores as well as to the three composite performance scores. Separate analyses were conducted for the straight and level warm-up portion and for the six Vertical S trials. This amounts to a total of 32 separate analyses of variance. Since analyses on single variable scores permit evaluation of only one of five recorded variables of pilot performance at one time, primary consideration is given to reporting the results in terms of composite performance descriptors.

Straight and Level Warm-Up. A significant cues effect favoring SC was found for error amplitude, E_{Σ}, F (1, 28) = 5.22, $p < .05$. No other comparisons between the experimental groups were significant. Dunnett's

Table 5

Group Means for Cognitive Performance Measures

Groups	n	Percent correct on posttest	Time through program[a]	Time through posttest[a]	Program efficiency index
Systematic cues					
Low practice	8	78.54	23.13	8.75	3.30
High practice	8	86.32	44.38	6.88	2.01
Current cues					
Low practice	8	61.84	24.63	8.50	2.76
High practice	8	62.43	40.50	6.75	1.76
No cues (control)	7	---	16.71	---	---

[a]in minutes

tests comparing each of the experimental groups with the independent control group did not reveal any significant differences.

Mean group scores on the three composite performance descriptors are shown in Table 6. Analysis of variance tables are included in Appendix P.

Vertical S Trials. In order to obtain information about the effects of instructional cues (Factor A) and practice (Factor B) over the course of the six trials, trials was included in the analyses of this portion as a within-subjects factor (Factor D). Mean group scores on each trial for the three composite performance descriptors are shown in Table 7 through 9 ; mean group scores averaged over trials are shown in Table 10. The analysis of variance tables are shown in Table 11 through 13.

Significant trials effects were found for error amplitude, F (5, 140) = 3.14, $p < .05$, for hit rate, F (5, 140) = 9.57, $p < .001$, and for percent time on criterion, F (5, 140) = 5.50, $p < .001$. A significant trials x instructional cues interaction was found for percent time on criterion, F (5,140) = 2.49, $p < .05$.

The performance curves for the three levels of instructional cues over six trials (representing the trials x instructional cues interaction) are shown in Figures 3, 4 and 5 for each of the composite performance descriptors. Linear trend contrasts over six trials between systematic cues and current cues revealed significant differences between these two levels of instructional cues for error amplitude, F (1, 28) = 5.26, $p < .05$, and for percent time on criterion, F (1, 28) = 9.31, $p < .005$. Group performances within trials were evaluated by t tests. Significant differences were found for the two levels of instructional cues on each of the three composite performance descriptors (see Table 14).

Table 6

Mean Group Scores for Perceptual Motor Performance during Straight and Level Warm-up

Groups	n	Performance descriptors		
		Error amplitude[a]	Hit rate[a]	Percent time on criterion[a]
Systematic cues				
Low practice	8	2.63	2.69	290.60
High practice	8	2.99	3.03	332.49
Current cues				
Low practice	8	5.66	2.62	282.93
High practice	8	3.86	2.85	307.76
No cues	7	3.79	2.96	310.01

[a]summed across variables

Table 7

Mean Group Scores for Perceptual Motor Performance over Six Vertical S Trials (Error Amplitude)[a]

Groups	n	Trials 1	2	3	4	5	6
Systematic cues							
Low practice	8	5.57	4.35	4.75	4.30	4.52	4.55
High practice	8	6.19	5.22	5.02	5.05	5.83	8.73
Current cues							
Low practice	8	9.87	7.26	5.95	5.56	6.28	6.40
High practice	8	9.12	7.54	6.56	5.80	6.84	5.49
No cues	7	5.19	4.34	4.58	6.10	4.67	4.26

[a]summed across variables

Table 8

Mean Group Scores for Perceptual Motor Performance over Six Vertical S Trials (Hit Rate)[a]

Groups	n	Trials 1	2	3	4	5	6
Systematic cues							
Low practice	8	2.37	2.42	2.77	2.84	2.66	2.67
High practice	8	2.12	2.49	2.45	2.52	2.46	2.44
Current cues							
Low practice	8	1.91	2.12	2.53	2.65	2.36	2.56
High practice	8	1.87	2.14	2.34	2.35	2.22	2.46
No cues	7	2.48	2.56	2.56	2.51	2.92	2.88

[a]summed across variables

Table 9

Mean Group Scores for Perceptual Motor Performance over Six Vertical S Trials (Percent Time on Criterion)[a]

Groups	n	Trials					
		1	2	3	4	5	6
Systematic cues							
Low practice	8	221.11	235.24	245.39	243.39	235.27	232.81
High practice	8	210.46	231.86	226.61	226.11	216.74	206.34
Current cues							
Low practice	8	172.93	207.28	218.04	240.84	219.00	219.37
High practice	8	179.48	205.13	217.83	226.05	205.81	237.52
No cues	7	230.56	244.48	246.42	221.77	250.78	252.62

[a]summed across variables

Table 10

Mean Group Scores for Perceptual Motor Performance

Averaged over Trials

(All Descriptors)

Groups	n	Performance descriptors		
		Error amplitude[a]	Hit rate[a]	Percent time on criterion[a]
Systematic cues				
Low practice	8	4.67	2.62	235.53
High practice	8	6.01	2.41	219.69
Current cues				
Low practice	8	6.89	2.35	212.91
High practice	8	6.89	2.23	211.97
No cues	7	4.86	2.65	241.11

[a]summed across variables

Table 11

Analysis of Variance: Error Amplitude E_{Σ}

Source	SS	df	MS	F	p
Total	2436.03	191	12.75		
Between	1112.66	31	35.89		
Instruct. cues (A)	115.20	1	115.20	3.38	.0735
Practice (B)	21.41	1	21.41	.63	.5593
A x B	21.26	1	21.26	.62	.5577
Error	954.79	28	34.10		
Within	1323.37	160	8.27		
Trials (D)	119.52	5	23.90	3.14	.0104
D x A	86.30	5	17.26	2.26	.0508
D x B	13.09	5	2.62	.34	.8856
D x A x B	37.07	5	7.41	.97	.5619
Error	1067.39	140	7.62		

Table 12

Analysis of Variance: Hit Rate H_{Σ}

Source	SS	df	MS	F	p
Total	55.99	191	.29		
Between	30.72	31	.99		
Instruct. cues (A)	2.46	1	2.46	2.56	.1172
Practice (B)	1.34	1	1.34	1.40	.2463
A x B	.08	1	.08	.09	.7649
Error	26.84	28	.96		
Within	25.27	160	.16		
Trials (D)	6.13	5	1.23	9.57	.0000
D x A	.55	5	.11	.85	.5164
D x B	.56	5	.11	.88	.5028
D x A x B	.083	5	.02	.13	.9835
Error	17.94	140	.128		

Table 13

Analysis of Variance: Percent Time on Criterion T_{Σ}

Source	SS	df	MS	F	p
Total	348177.05	191	1822.92		
Between	167930.15	31	5417.10		
Instruct. cues (A)	11048.99	1	11048.99	2.05	.1602
Practice (B)	3375.90	1	3375.90	.63	.5589
A x B	2667.77	1	2667.77	.49	.5059
Error	150837.49	28	5387.05		
Within	180246.90	160	1126.54		
Trials (D)	26887.57	5	5377.51	5.50	.0003
D x A	12200.56	5	2440.11	2.49	.0333
D x B	1647.53	5	329.51	.34	.8896
D x A x B	2661.17	5	532.23	.54	.7444
Error	136850.05	140	977.50		

Table 14

t tests for Groups A & B (Systematic Cues)

versus Groups C & D (Current Cues)

for Trials 1 and 2[a]

Composite performance descriptor	Trials 1	Trials 2
Error amplitude	$t = 2.95$ $p < .05$	$t = 2.13$ $p < .05$
Hit rate	$t = 5.00$ $p < .001$	$t = 2.39$ $p < .05$
Percent time on criterion	$t = 3.58$ $p < .01$	$t = 2.49$ $p < .05$

[a] t tests non-significant for all contrasts on Trials 3 through 6.

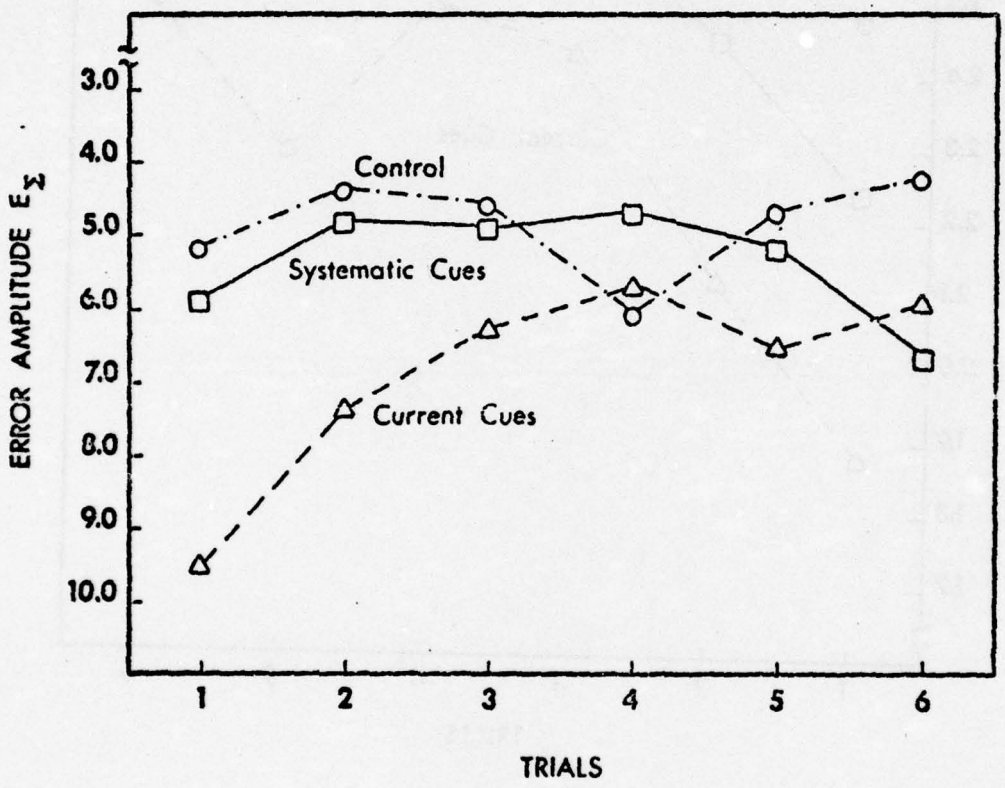


Figure 3. Perceptual motor performance as measured by error amplitude (scores summed across variables) for three levels of cues over six trials (A x D interaction).

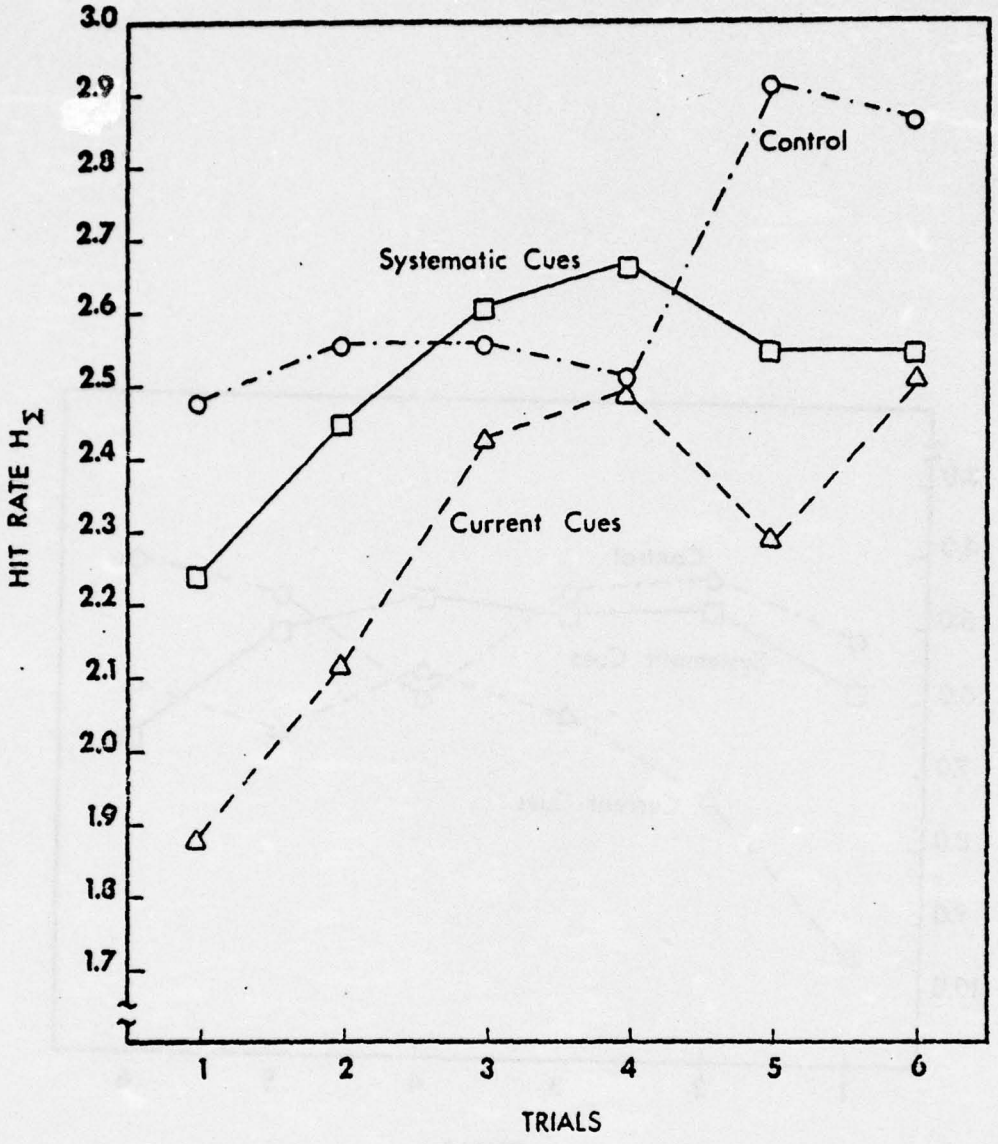


Figure 4. Perceptual motor performance as measured by hit rate (scores summed across variables) for three levels of cues over six trials (A x D interaction).

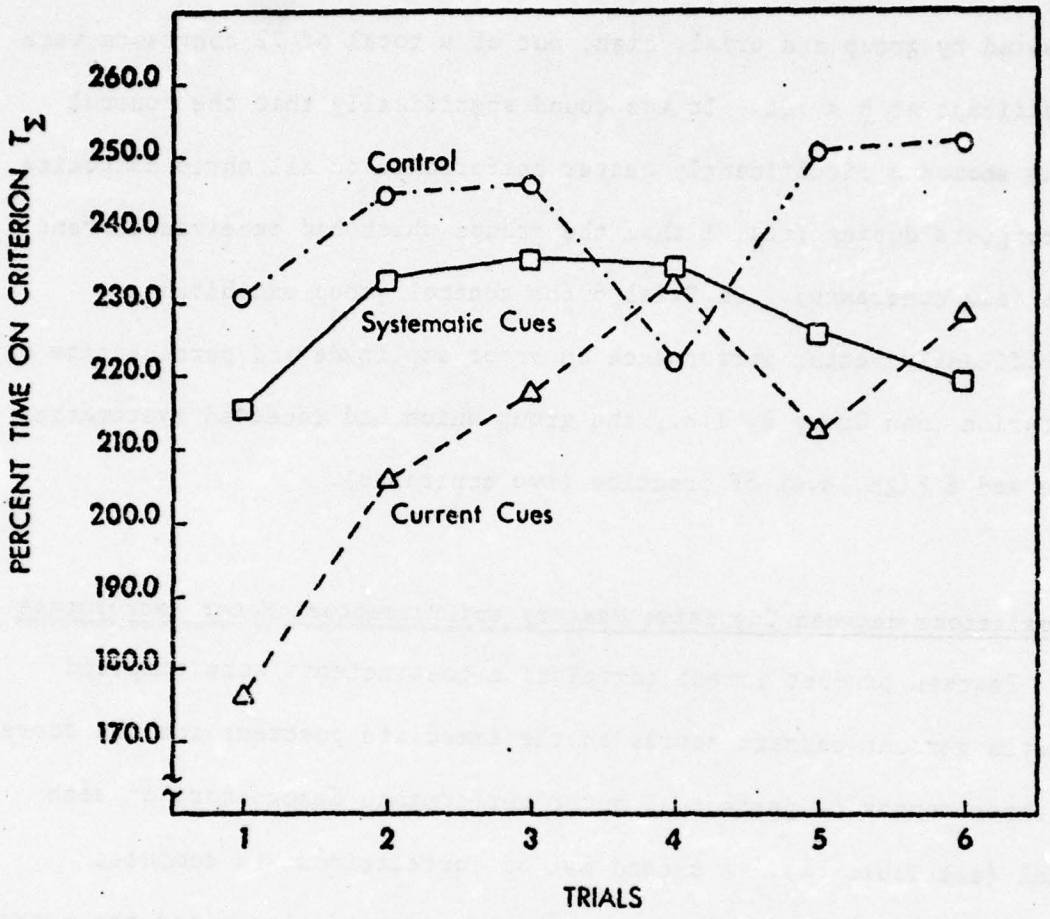


Figure 5. Perceptual motor performance as measured by percent time on criterion (scores summed across variables) for three levels of cues over six trials (A x D interaction).

Dunnett's tests comparing each of the four experimental groups with the independent control group revealed no significant difference between mean performance scores over all six trials. When performance was compared by group and trial, eight out of a total of 72 contrasts were significant at $p < .05$. It was found specifically that the control group showed a significantly better performance on all three composite descriptors during Trial 1 than the groups which had received current cues (six contrasts). On Trial 6 the control group exhibited a significantly better performance on error amplitude and percent time on criterion than Group B, i.e., the group which had received systematic cues and a high level of practice (two contrasts).

Correlations between Cognitive Mastery and Perceptual Motor Performance

Pearson product moment correlation coefficients were computed between percent correct scores on the immediate posttest and the scores on three composite perceptual motor performance descriptors on each trial (see Table 15). A second set of correlations was computed between percent correct scores on the immediate posttest and the scores on three composite perceptual motor performance descriptors for the straight and level warm-up period and for Vertical S trial period averaged over the trials (see Table 16). None of the correlations reached the .05 level of significance ($r \leq .268$).

Questionnaire

Analysis of the postexperimental questionnaire revealed no distinguishable differences between groups in the answers to Questions 1 through 6, 8, 9 and 11 through 14.

Table 15

Correlations between Cognitive Mastery and Perceptual Motor Performance on Six Trials

Composite performance descriptor	Trials 1	2	3	4	5	6
Error amplitude	.089	.035	-.019	-.168	-.004	-.054
Hit rate	.238	-.106	-.113	-.003	-.053	-.097
Percent time on criterion	.012	-.078	-.113	.194	.028	-.001

Table 16

Correlations between Cognitive Mastery

and Perceptual Motor Performance

during the Warm-up and during the Trial Period

Composite performance descriptor	Straight and level warm-up period	Mean performance over six trials of Vertical S
Error amplitude	.046	.034
Hit rate	.047	.064
Percent time on criterion	-.078	.041

The answers to Question 7 showed an effect for instructional cues, F (1, 28) = 7.29, $p < .05$. Groups which had received systematic cues reported less use of trim.

In Question 9 subjects were asked to rank order five instructional procedures. The resulting rank order based on the responses by all subjects regardless of group is shown in Table 17.

In Question 10 subjects were asked to rate the instructional treatments they had received during cognitive pretraining on four Likert - type scales (1 = low, 5 = high). The group means of these ratings are shown in Table 18 together with the mean overall ratings. Subjects in the current cues/high practice condition rated the treatments significantly lower on every scale except on usefulness of drawings. The overall rating showed a significant practice effect, F (1, 28) = 5.20, $p < .05$, and a significant instructional cues x practice interaction effect, F (1, 28) = 7.26, $p < .05$, both of which are attributable to the low overall rating by the current cues/ high practice group. The latter also differed significantly from the control group, F (1, 13) = 12.43, $p < .01$.

Table 17

Subject Preference of Five Instructional Procedures

Instructional procedure	Rank	Mean assigned rank	Standard deviation
Programmed instruction plus instructor briefing	1	1.38	.72
Selfstudy plus instructor briefing	2	1.89	.83
Programmed instruction only	3	3.50	.88
Instructor briefing only	4	3.53	.92
Selfstudy only	5	4.56	.88

Table 18

Mean Subject Ratings of the Experimental Treatments Received during Cognitive Pretraining[a]

Group	n	Usefulness	Thoroughness	Usefulness of drawings	Liking	Overall rating
Systematic cues						
Low practice	8	4.00	4.38	3.38	3.63	3.85
High practice	8	3.50	4.38	3.63	3.75	3.82
Current cues						
Low practice	8	3.88	4.25	3.75	4.25	4.03
High practice	8	2.88	2.63	2.13	2.75	2.60
No cues	7	3.29	4.00	4.29	4.14	3.93

[a] 1 = low, 5 = high

Discussion

The primary goal of the present study was the identification of variables which influence transfer from cognitive pretraining to perceptual motor skill acquisition. The results clearly support the central hypothesis that the direction of transfer is dependent on the type of verbal instructional cues which were learned during cognitive pretraining. Systematically developed instructional cues led to more precise perceptual motor behavior than currently operational cues, which appear to inhibit rather than facilitate performance. The results did not confirm the hypothesis that the amount of cognitive practice would be directly related to the amount of transfer. Variations in the amount of cognitive practice did not result in subsequent variations of perceptual motor performance.

The most significant specific finding of the cognitive phase of the study is the superior posttest performance of groups which had received systematic cues. Subjects in this treatment condition achieved posttest scores which were on the average 17 percentage points above those of subjects who had received current cues. These higher scores were achieved at no expense in terms of time through program. It follows that systematic cues were much more readily retained or, to put it differently, that systematic cues may be considered to be more efficient verbal cognitive mediators than current cues.

The amount of cognitive practice with a given set of cues did not influence posttest scores but it did lead to differences in posttest time. Subjects in the high practice conditions had significantly

shorter posttest times than subjects in the low practice conditions. Since the posttest consisted of a straightforward reproduction of a list of cues, this result shows clearly that the cues were more readily recalled by subjects in the high practice condition. It is important to note, however, that greater readiness of recall does not entail greater precision of recall. Readiness of recall or cognitive availability of cues appeared to be a function of practice, whereas precision of recall varied with the type of instructional cue.

In short, both independent variables resulted in significant cognitive performance differences. The results of the perceptual motor phase of the study show partially corresponding performance differences, indicating partial transfer from cognitive learning to perceptual motor skill acquisition.

The two levels of instructional cues which led to differences in the precision of cognitive performance led to similar differences in the precision of perceptual motor performance. The relatively high and stable performance of the systematic cues groups contrasts initially with the much lower and gradually increasing performance of the current cues groups. By Trial 4 all experimental groups had merged at a performance level which represents a performance ceiling for all but the control group.

These differential performance patterns indicate that systematic cues facilitate perceptual motor performance in a way which permits the learner to perform at or near ceiling performance from the beginning. Current cues, by comparison, initially inhibit performance. This inhibiting effect gradually disappears as indicated by the gradual convergence of the essentially flat performance curves (see Figure 3

and Figure 5) for systematic cues and the steadily ascending curves for current cues. In the absence of a true zero point of transfer effects it is of course impossible to define positive or negative transfer effects in absolute terms. Statements about transfer can therefore only be made in relative terms. Thus, relative to current cues, systematic cues are facilitative or show positive transfer effects or, relative to systematic cues, current cues are inhibitory or show negative transfer effects.

The performances of the control groups in the present and in the preceding study (Brecke et al., 1974) add some reference points to these considerations. The control group in the preceding study received merely the maneuver objective and its subsequent perceptual motor performance was at the same level as that of the current cues group. The control group subjects in the present study received the maneuver objective and were asked to write down the steps they would follow in executing the maneuver, which essentially amounts to asking the subjects to analyze the maneuver and to supply their own cues. As the Figures 3, 4 and 5 show, the control group in the present study performed at or above the performance level of the systematic cues group. This result, which is in agreement with the superior performance for the Analyzer group in the study by Renshaw et al. (1928), provides a positive boundary value of transfer with respect to the treatment conditions investigated so far. In relation to this boundary value systematic cues can be considered maximally effective mediators of perceptual motor skill, whereas current cues must be considered to be considerably less effective. The assumption that the direction of transfer is a

function of the type of instructional cue is therefore supported at least in relative terms by the results of this study.

The two levels of cognitive practice which resulted in significantly different degrees of cognitive availability of a given type of instructional cues did not lead to the predicted differences in perceptual motor performance. If the hypothesis of a direct relationship between amount of cognitive practice and amount of transfer would have been borne out, the performance differences between systematic cues and current cues would have been smaller for low practice conditions than for high practice conditions. The results did not show any significant performance differences due to practice effects, even though the trial means (Tables 7 through 9) indicate a tendency towards lower performance levels for high practice conditions.

It is speculated that the failure to find overall significant effects for the practice variable by regular analysis of variance procedures was at least to some extent a consequence of the extreme instability of the T-4G simulator. This instability led to an information processing load which was considerably higher than it would have been if the simulator would have reacted like the real aircraft or the regular training simulator. Evidence to this effect are the answers to Questions 11 and 12 of the questionnaire. All but seven of the 39 subjects indicated that the simulator used in the experiment was "harder to fly" than either the aircraft or the regular training simulator. Increased information processing loads led to the common phenomenon of over-control, which in turn resulted in performance variances high enough to mask out any existing effects of the practice variable.

The high and heterogeneous variances associated with the perceptual motor data of the experimental groups also provide an explanation for the lack of significant correlations between cognitive mastery and perceptual motor performance.

In summing up the outcomes of this study with respect to its first objective, the following statements appear justified:

1. The results show clearly that transfer from cognitive pretraining to perceptual motor learning is affected by the type of verbal instructional cue learned during cognitive pretraining.

2. The results of the study provide a baseline for the investigation of practice as a second independent and manipulable variable of cognitive pretraining. Increased levels of cognitive practice appear to lead to greater cognitive availability of the instructional cues which in turn should lead to distinguishable perceptual motor performance differences.

3. Instructional cue was defined as an independent variable on the basis of a conceptual framework which includes both information theory and control theory. The results indicate that this conceptual framework is highly appropriate in the context of perceptual motor learning.

4. The conceptual framework used in this study also represents a common denominator for the several research approaches to the problem of the cognitive antecedents of perceptual motor learning which were discussed in Chapter 2.

The second objective of the study was the discovery and validation of prescriptive principles for the design of perceptual motor instruction. On both counts, in terms of validation of existing design principles

as well as in terms of discovery of new design principles, the study resulted in the attainment of the second objective.

The instructional design devices which were used in the preceding experiments were used again in the present study. The same maneuver analysis, the same criteria for the distinction between functional and nonfunctional cues and the same procedures for cue generation were employed to produce a different type of instructional treatment. In the preceding experiment an approximation of the current standard USAF instructional procedure was used consisting of a prose text and an instructor briefing which was simulated by a TV presentation. In the present study the instructional treatment consisted of programmed instruction without a briefing. The predicted instructional effects were in both cases confirmed by the experimental results which amounts to an empirical validation of the design devices over two types of instructional treatments.

The results of the study also provided empirical evidence for two previously uninvestigated considerations for the design of perceptual motor instruction.

The high practice version of the instructional treatments was created by a straightforward repetition of identical mastery items. This manipulation led on the one hand to a significant decrease of the instructional efficiency of the program and on the other hand to negative attitudes on the part of the learners. The decrease of instructional efficiency was evidenced by the sharp increase of program time without concurrent increase in posttest scores. Evidence for the negative learner attitudes comes primarily from the significantly lower ratings

for the instructional treatments which were given by Group D, the group which received current cues and high practice. It follows that instructional programs which are designed to provide cognitive pretraining should not incorporate repetitive practice of the type used in this study.

A second consideration for the design of perceptual motor instruction arises out of the performance exhibited by the control group. This group showed a very high performance for a very low investment in terms of cognitive pretraining time and an even lower investment in instructional development. From the standpoint of efficiency the instructional treatment administered to the control group is definitely superior to all other instructional treatments administered in this experiment. An instructional procedure which merely supplies the learner with an objective or with a precise idea of the desired goal performance and enlists the ingenuity of the learner in finding ways to attain this goal performance thus appears to be a more economical way to raise the instructional efficiency of pilot training than supplying the learner with explicit "how-to" cues which are very costly to develop.

The question, "Which one of these instructional procedures should be employed?", is, however, not only an economic question. It touches broader curricular goals as well. If the learner is supplied with an explicit set of instructional cues for each flight maneuver, he is essentially faced with the task of learning sets of procedures, i.e., lists of carefully sequenced sentences or sentence fragments. This may very easily lead to rote learning and mindless regurgitation. Even if that danger can be avoided, which is doubtful, this kind of instructional procedure is hardly conducive to the development of judgment, the

ability to analyze flying tasks and the ability to make autonomous decisions. It therefore appears that an instructional treatment which offers the possibility of attaining a high level of perceptual motor performance on the one hand and a high level of generic cognitive skills on the other hand would be most advantageous.

The findings of the study are limited in their generalizability to other maneuvers and to other teams of subject matter experts plus instructional designers. Another limitation to generalizability arises from the fact that the present as well as the preceding experiment involved only "one-shot" treatments. Future research should therefore extend the instructional design procedures to other maneuvers, use different development teams and examine the effects of various types of cognitive pretraining over repeated experimental sessions and longer time periods.

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Appendix A

Summary and Raw Data on Subject Characteristics

Summary Table: Means of Subject Characteristics by Groups

		Characteristics			
Group	n	Age	Hours of prior training	Hours in T-37	Hours in Simulator
A	8	23.87	74.94	10.46	3.37
B	8	23.37	103.37	10.37	2.56
C	8	22.62	20.56	10.32	2.00
D	8	23.25	40.81	8.55	2.37
E	7	23.43	88.43	12.37	2.43

Raw Data for the Subject Characteristic

Age

	Groups				
Subject #	A	B	C	D	E
1	27	22	23	25	26
2	22	27	22	23	23
3	23	21	22	22	23
4	22	27	22	22	26
5	26	23	22	23	22
6	23	23	23	23	22
7	22	22	25	22	22
8	26	22	22	26	--

Raw Data for the Subject Characteristic

Hours of Prior Training

	Groups				
Subject #	A	B	C	D	E
1	127.0	250.0	0.0	48.0	100.0
2	38.0	100.0	0.0	36.0	150.0
3	36.0	37.0	36.0	36.5	36.0
4	87.0	55.0	36.5	36.0	170.0
5	180.0	120.0	30.0	40.0	27.0
6	36.5	35.0	32.0	35.0	36.0
7	60.0	60.0	0.0	25.0	100.0
8	35.0	170.0	30.0	70.0	---

Raw Data for the Subject Characteristic

Hours in T-37

	Groups				
Subject #	A	B	C	D	E
1	7.0	13.0	15.7	16.0	9.5
2	10.0	8.0	13.0	10.7	14.0
3	11.0	9.5	9.4	6.9	16.6
4	12.0	15.5	13.0	5.0	13.0
5	7.5	4.0	7.0	2.8	12.0
6	12.0	11.0	5.5	7.0	6.5
7	12.0	10.0	12.0	11.0	15.0
8	12.0	12.0	7.0	9.0	---

Raw Data for the Subject Characteristic

Hours in Simulator

	Groups				
Subject #	A	B	C	D	E
1	4.0	1.0	1.5	4.0	1.5
2	2.5	4.5	4.5	3.0	3.0
3	2.5	3.0	1.5	1.5	1.5
4	3.5	2.0	3.0	2.0	2.0
5	3.0	1.0	1.5	1.0	3.0
6	3.0	1.0	1.5	2.0	3.0
7	4.0	2.0	1.5	2.5	3.0
8	4.5	6.0	1.0	3.0	---

Appendix B

Experimental Information for the Participating Subjects

FOR YOUR INFORMATION

1. You are participating in an experiment run by scientists from the Department of Educational Technology at Arizona State University. The project is sponsored under a grant from the Air Force Office of Scientific Research.

2. Your performance during the experiment will not affect your class standing in any way. You will remain an anonymous "subject" in all reports on this experiment. This is not an evaluation situation or testing situation for you.

3. One of the experimenters will "walk" you through the whole sequence of events. Here is a brief outline of the procedure:

   a) First you will go through a "Study Phase." You will be provided with instructional materials for a certain flight maneuver. Study the materials carefully. Proceed at a rate which is comfortable to you.

   b) There will be a test included at the end of the instructional materials for almost everybody. Do your best on it but don't be afraid to make a mistake or leave a gap if you don't know the answer.

   c) The Study Phase is followed by a "Flying Phase" in the simulator. Here is the outline for the "mission":

      -Get in and put on the headset
      -Communications check with experimenter
      -Lower Canopy
      -Take controls and fly straight + level for 5 min. (Simulator will be at 15000 ft, 160 Kias and take-off trim set).
      -Fly your assigned maneuver six times.

      Note: The experimenter will tell you when to start a maneuver by saying: START NOW.
      You tell the experimenter when you finish the maneuver by saying: FINISHING NOW.

      -Between maneuvers fly straight and level at 15000' and 160 knots.

4. When you are through with your maneuvers, you get out of the trainner and fill out a brief questionnaire. There will be no de-briefing. When you have completed the questionnaire you may leave and return to your regular duties.

5. When the data are analyzed you will receive a briefing on what the experiment was all about.

Appendix C

Statement of Consent

STATEMENT OF CONSENT

PROJECT: Cues, Feedback and Transfer in Undergraduate Pilot Training

Principal Investigator: Dr. R.C.Haygood

In return for the opportunity of participating as a subject in a scientific research investigation and for other consideration, I hereby authorize the performance upon me of the following procedure:

1. Verbal textual instruction on a specific flight maneuver
2. Performance of the maneuver in an instrument trainer
3. Filling out a questionnaire designed to elicit my opinion on the instruction received

This consent I give voluntarily and after the nature of the experimental procedure, the known dangers, and the possible risks and complications have been fully explained to me. I knowingly assume the risks involved and I am aware that I may withdraw my consent and discontinue participation at any time without penalty to myself.

	Name	Date	Signature	Witness
1	ALAN L RUST	6MAR74	Alan L Rust	
2	ALAN D [illegible]	6 MAR 74	[illegible]	
5	JOHN E DEES JR	6 MAR 74	John E Dees	
4	ELWIN D Prah	6MAR 74	Elwin D Prah	
5	Terry L Godby	6 Mar 74	Terry Godby	
6	Rodney E. Hazen	6 Mar 74	[illegible]	
7	KEVIN S [illegible]	6 MAR 74	[illegible]	
8	EDWARD T [illegible]	7 MAR 74	[illegible]	
9	WILLIAM H [illegible]	7 MAR 74	[illegible]	
10	JAMES T DAUBERT	7 MAR 74	[illegible]	
11	[illegible]	7 Mar 74	[illegible]	
12	GREGORY T [illegible]	7 MAR 74	[illegible]	

Page 2 of STATEMENT OF CONSENT

	Name	Date	Signature	Witness
13	Bruce A Brown	7 Mar 74	Bruce A Brown	
14	Hugust H. Scherer	7 MAR 74	August H Scherer	
15	WARREN E THOMAS	8 MAR 74	Warren E. Thomas	
16	John E Fredericks	8 MAR 74	John E Fredericks	
17	Daniel F. Connors	8 Mar 74	Daniel F Connors	
18	Dennis P. Cooley	8 MAR 74	Dennis P Cooley	
19	Stephen A White	8 MAR 74	Stephen A White	Witness
20	James E Meller	8 MAR 74	James E Meller	
21	Ellis D. Nelson	11 Mar 74	Ellis D Nelson	
22	Gary E. Gossett	11 MAR 74	Gary E. Gossett	
23	Kenneth [illegible]	11 Mar 74	[illegible]	
24	James E McGaha	11 MAR 74	James E McGaha	
25	Francis E [illegible]	11 Mar 74	Francis E [illegible]	
	[illegible]	11 [illegible]	[illegible]	
	John M Hewlett	12 MAR 74	John M Hewlett	
28	Thomas Gonzales	12 MAR 74	Thomas Gonzales	
29	Jorge L Fernandez	12 MAR 74	Jorge L Fernandez	
30	Gary M. Henson	12 MAR 74	Gary M Henson	
	Robert P Ullman	12 Mar 74	Robert P Ullman	
	James J Schiermeyer	12 MAR 74	J Schiermeyer	
	Douglas R Barbick	13 MAR 74	D R Barbick	
34	Krzanowski Peter J	13 MAR 74	[illegible]	
	Brent R Barker	13 MAR 74	Brent R Barker	

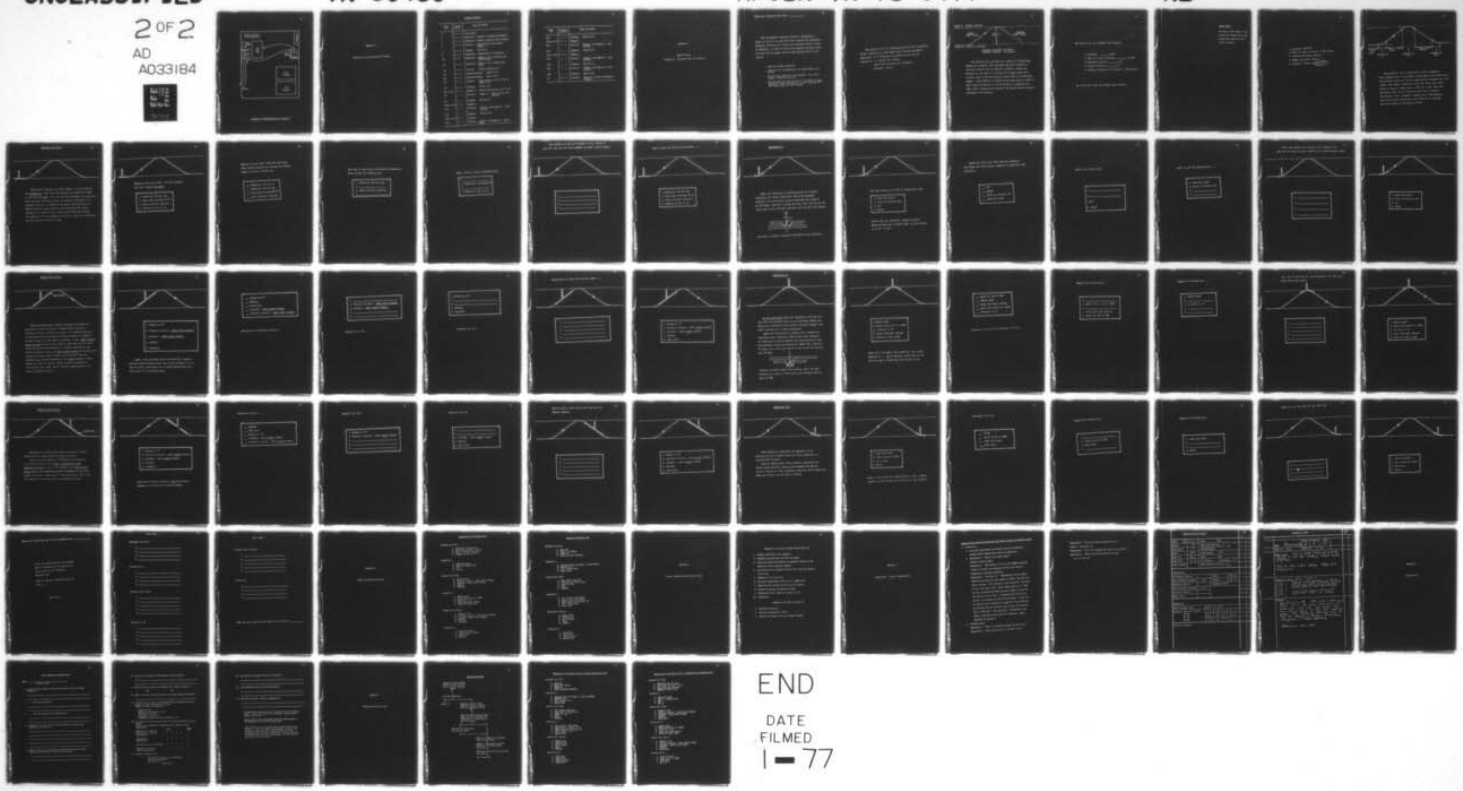
	Name	Date	Signature	Witness
36	JAMES B. ELLEDGE	15 MAR 74	James B. Elledge	
37	John F. Bivona	15 MAR 74	John F. Bivona	
38	Douglas Walton	15 MAR 74	Douglas Walton	
39	CLAWSON, Frank W	15 Mar 74	Frank W. Clawson	
40	GEORGE MITCHELL W.	18 MAR 74	[illegible]	
41				
42				
43				
44				
45				

Appendix D

Layout of the Experimental Facility

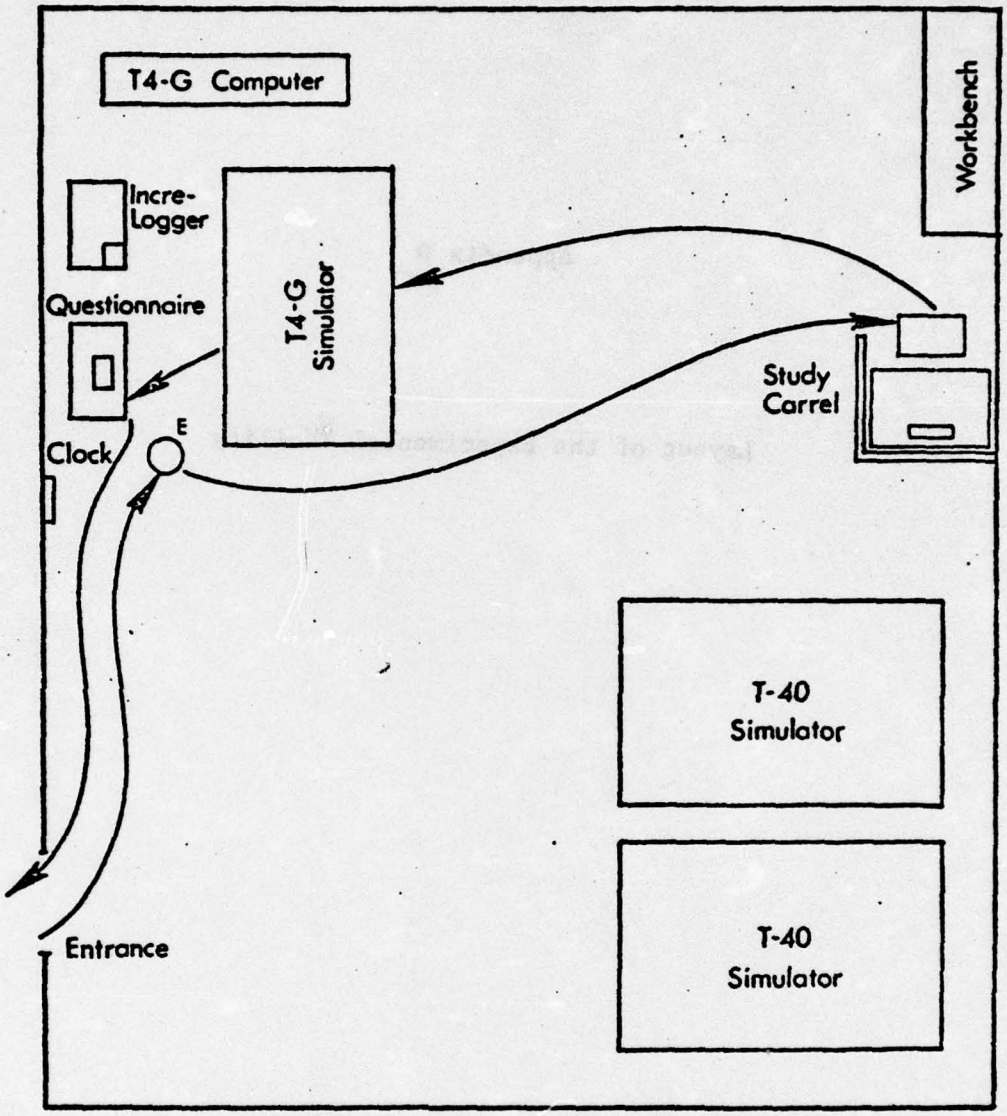
AD-A033 184 ARIZONA STATE UNIV TEMPE DEPT OF EDUCATIONAL TECHNOLOGY F/G 5/9
CUES AND PRACTICE IN FLYING TRAINING.(U)
APR 75 F H BRECKE AF-AFOSR-2128-71
UNCLASSIFIED TN-50430 AFOSR-TR-76-0477 NL

2 OF 2
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END

DATE
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1-77



LAYOUT of EXPERIMENTAL FACILITY

Appendix E

Structure of the Instructional Programs

Program Structure

Frame #	Program A B C D E	Type and Content
1	+ + + + +	Instructions
2	+ + + + +	Expository: Purpose of learning the maneuver
3	+ + + + +	Expository: Maneuver objective (with drawing)
4	+ + + + +	Practice: Name objective data (formal prompt)
5	+ + + + +	Feedback: KCR for #4
6	+ + + + +	Expository: Segmentation of the maneuver
7/1	+ + + +	Expository: Segment 1 IC's, connected prose (with drawing)
7/2	+ + + +	Expository: Segment 1 IC's, ordered list (w.d.)
7/3	+ + + +	Practice: "Order scrambled list"
7/4	+ + + +	Practice/Feedback: "Name 2 IC's"
7/5	+ + + +	Practice/Feedback: "Name 2 IC's"
7/6	+ + + +	Practice: "Name complete list of 4 IC's in order" (w.d.)
7/7	+ + + +	Feedback: KCR for 7/6
8/1 to 8/7	+ + + +	Segment 2: Same fine-structure as 7/1 to 7/7
9/1	+ +	Practice: Segment 1: Name list of 4 IC's in order
9/2	+ +	Feedback: KCR for 9/1
10/1 to 10/7	+ + + +	Segment 3
11/1	+ +	Practice: Segment 1 and Segment 2: Name in order
11/2	+ +	Feedback: KCR for 11/1
12/1 to 12/7	+ + + +	Segment 4
13/1	+ +	Practice: Segment 2 and Segment 3: name in order

Frame #	Program A B C D E	Type and Content	
13/2	+ +	Feedback:	KCR for 13/1
14/1 to 14/7	+ + + +	Segment 5	
15/1	+ +	Practice:	Segment 3 and Segment 4: name in order
15/2	+ +	Feedback:	KCR for 15/1
16/1 to 16/7	+ + + +	Segment 6	
17/1	+ +	Practice:	Segment 4 and Segment 5: name in order
17/2	+ +	Feedback:	KCR for 17/1
18/1	+ +	Practice:	Segment 5 and Segment 6: name in order
18/2	+ +	Feedback:	KCR for 18/1
19	+ + + +	Posttest:	Name IC's in order for Segment 1 through 6

Appendix F

Sample Program

Treatment A: Systematic Cues, Low Practice

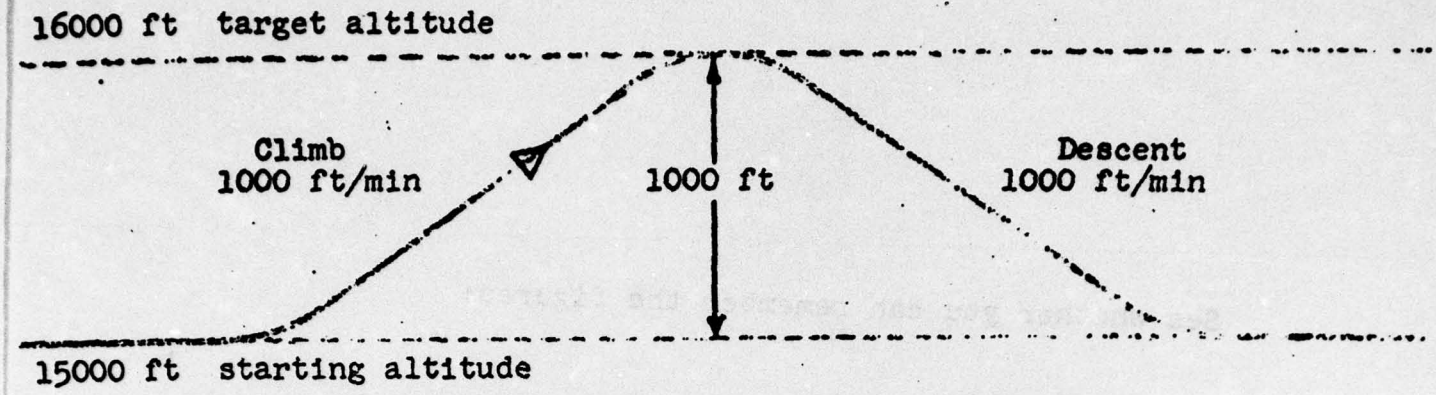
Mark your starting time here: _____

This programmed learning booklet is designed to teach you as much as possible about flying the instrument maneuver "Vertical S-A" before you actually touch a stick or throttle. In order to derive the maximum possible benefit from this program, follow these ground rules to the letter:

- Read each page carefully
- Complete all assignments on a page before you go on
- Do not peek ahead for the answers - you won't learn a thing if you do!
- Do the best you can but don't be afraid to make mistakes. Your performance on this program will not become part of your record.

The Vertical S-A is a training maneuver which simulates flight conditions as they might occur during instrument approaches. It is designed to provide pilots with an opportunity to improve two things:

- Speed and efficiency of crosscheck
- Aircraft control



Constant airspeed: 160 KIAS
Constant heading : as desired

The Vertical S-A consists of a series of alternating climbs and descents. From straight and level flight you can start either with a climb or a descent. During the mission you are about to fly you will always start with a climb. Each climb and descent covers 1000 ft of altitude change - from 15000 ft to 16000 ft and back down to 15000 ft. Each climb and descent is to be flown at a constant rate: 1000 ft/min. Heading and airspeed (160 KIAS) remain constant throughout the maneuver.

See whether you can remember the figures:

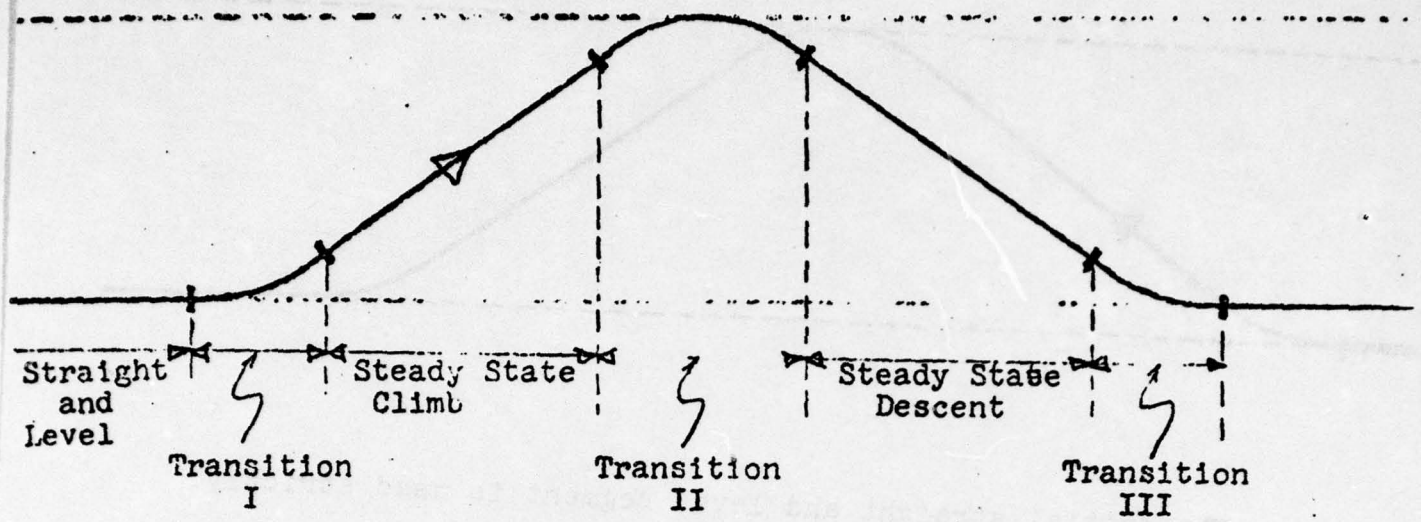
1. Airspeed: _____ KIAS
2. Rate of climb or descent: _____ ft/min
3. Starting altitude: _____ft
4. Target altitude: _____ft
5. Heading: Variable or constant? (Circle one)

Go to the next page and compare your answers.

Sample Insert

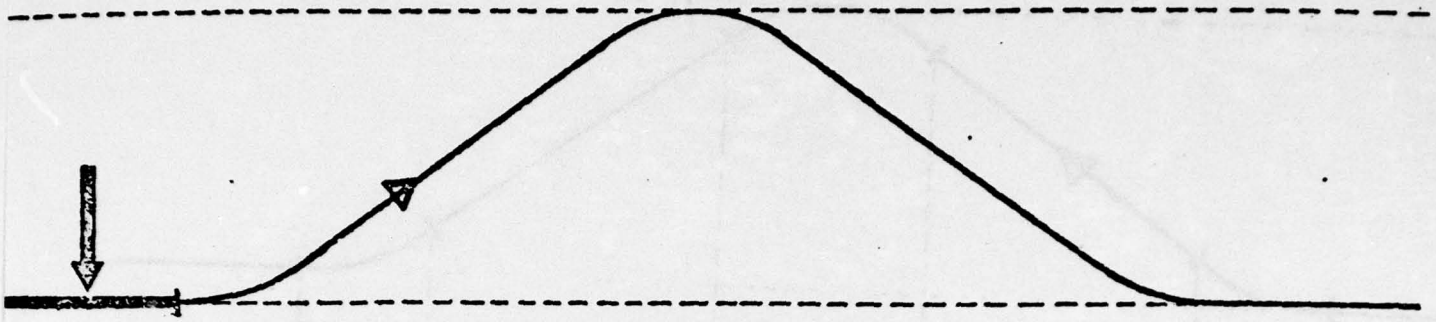
One sheet of blue paper of this quality was inserted after each frame which required an overt student response.

1. Airspeed: 160 KIAS
2. Rate of climb or descent: 1000 ft/min
3. Starting altitude: 15000 ft
4. Target altitude: 16000 ft
5. Heading: Variable or constant

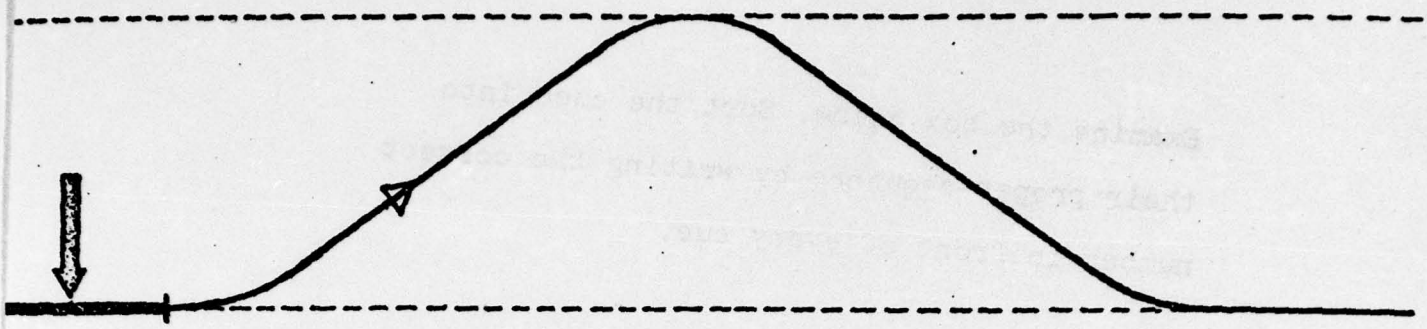


The maneuver can be divided into several segments. These segments are of two kinds: steady states and transitions. The maneuver starts out with a steady state: Straight and Level flight. Then comes a transition into the climb. The climb itself is again a steady state. After the climb comes the transition over the top from the climb into a descent. The descent itself is again a steady state. The maneuver ends with another transition, the level-off to straight and level flight at starting altitude.

Straight and Level



The initial straight and level segment is used strictly for preparation. Fine trim the aircraft for hands-off flight at 160 KIAS and keep this trim setting throughout the maneuver. Note the power setting it takes to maintain 160 KIAS at the assigned altitude. At 15000 ft the power setting should be 82±1%. Carefully adjust the attitude indicator for level indication in order to have a good pitch reference during the maneuver. Put the heading at the top of the J-2. Deviations are much easier to spot this way.



Remember these four cues for the straight and level segment in order :

1. Establish 160 and trim
2. Note power setting: 82±1%
3. Level attitude indicator
4. Heading on top of J-2

Examine the box below. Sort the cues into their proper sequence by writing the correct number in front of every cue.

___ Heading on top of J-2
___ Establish 160 and trim
___ Note power setting: 82±1%
___ Level attitude indicator

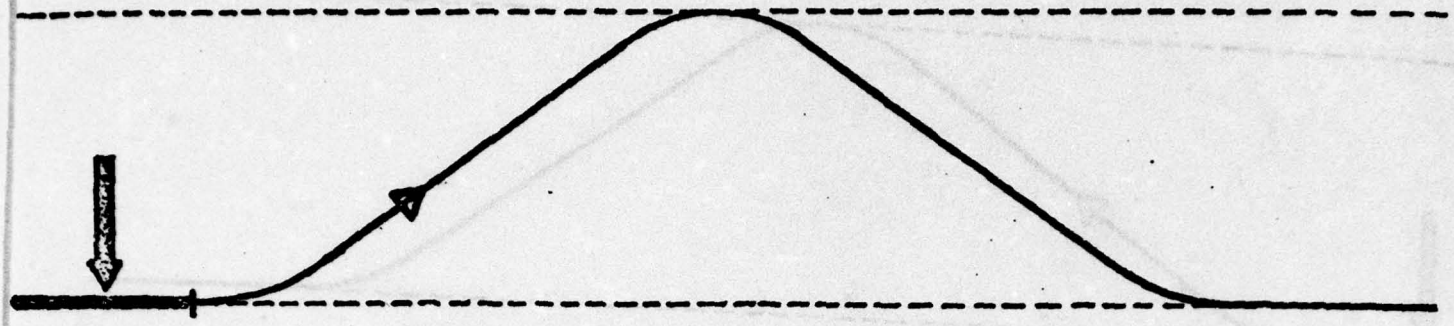
The list of cues below is obviously incomplete. Write in the two missing cues.

1. Establish 160 and trim
2. _____
3. Level attitude indicator
4. _____

Again, write in the two missing cues!

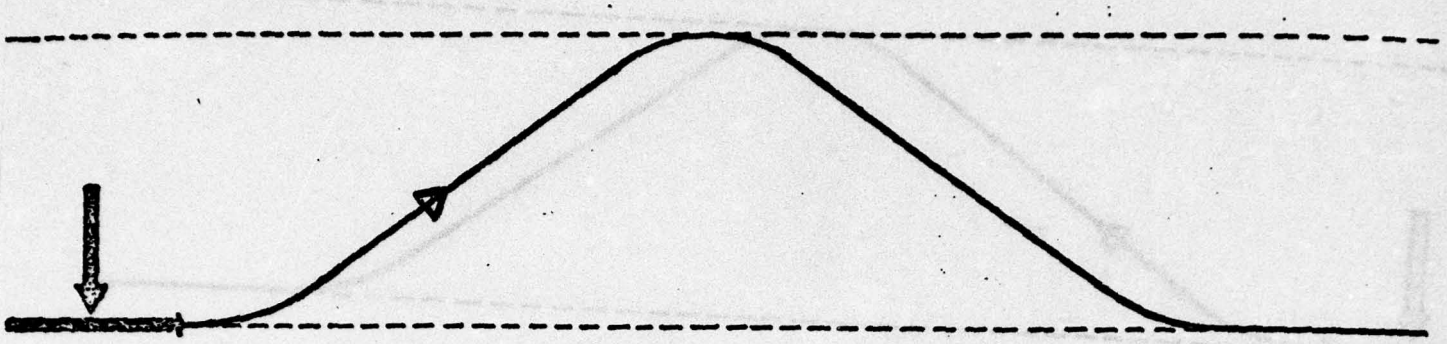
1. _____
2. Note power setting: 82±1%
3. _____
4. Heading on top of J-2

See whether you can now remember it all. Write in all the cues for the first segment in their correct order!



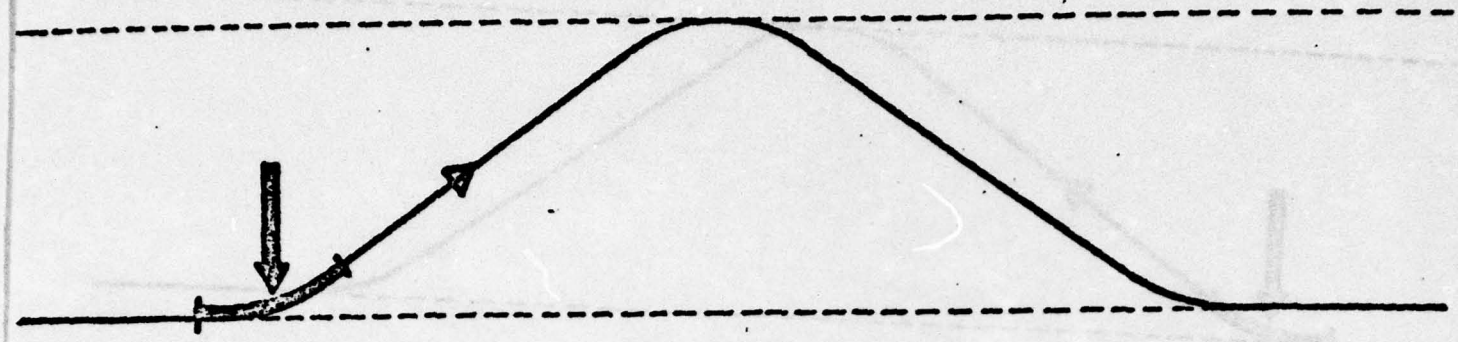
1. _____
2. _____
3. _____
4. _____

Here is what you should have written ...

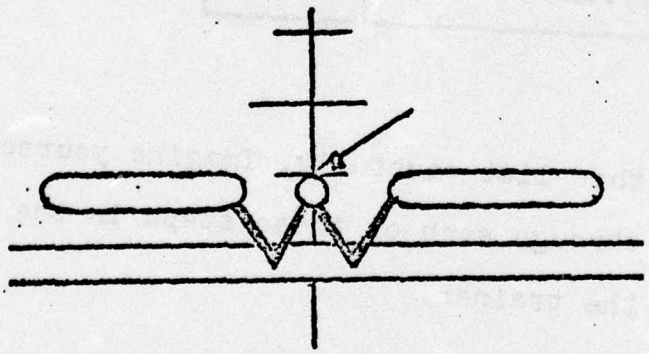


1. Establish 160 and trim
2. Note power setting: 82 1%
3. Level attitude indicator
4. Heading on top of J-2

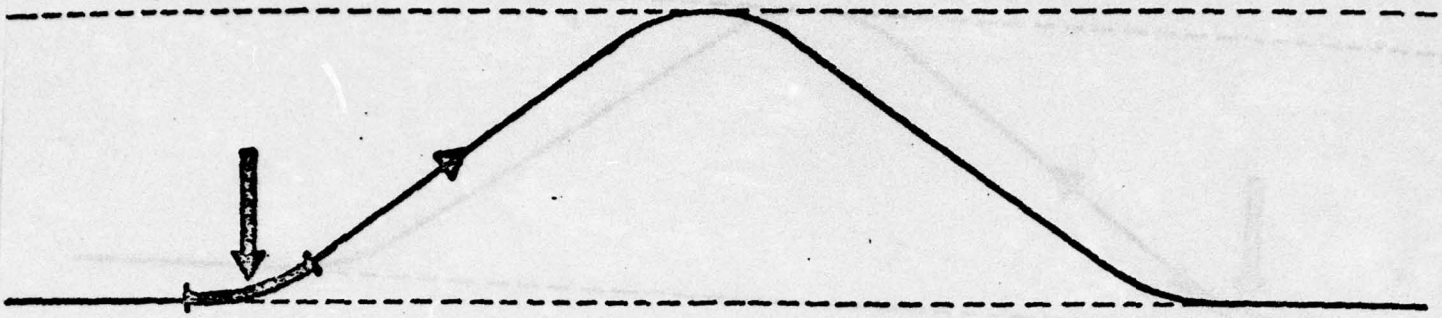
Transition I



Begin the transition by applying power at a smooth, continuous and fairly rapid rate. Watch the airspeed indicator and raise pitch so as to maintain the airspeed at 160 knots. Continue to raise the nose until the top of the center dot on the attitude indicator just touches the +5° mark.



Set power to 94±1% to maintain 160 KIAS at this attitude.



The same again in the form of abbreviated cues:

1. Lead with power
2. Pitch to maintain 160
3. +5°
4. 94±1%

Study this list carefully. Imagine yourself going through each of these steps in the airplane or in the trainer.

Study the list below. The cues are scrambled. Sort them into their proper sequence by numbering them correctly.

___ +5°

___ 94±1%

___ Pitch to maintain 160

___ Lead with power

Supply the missing cues!

1. _____

2. _____

3. +5°

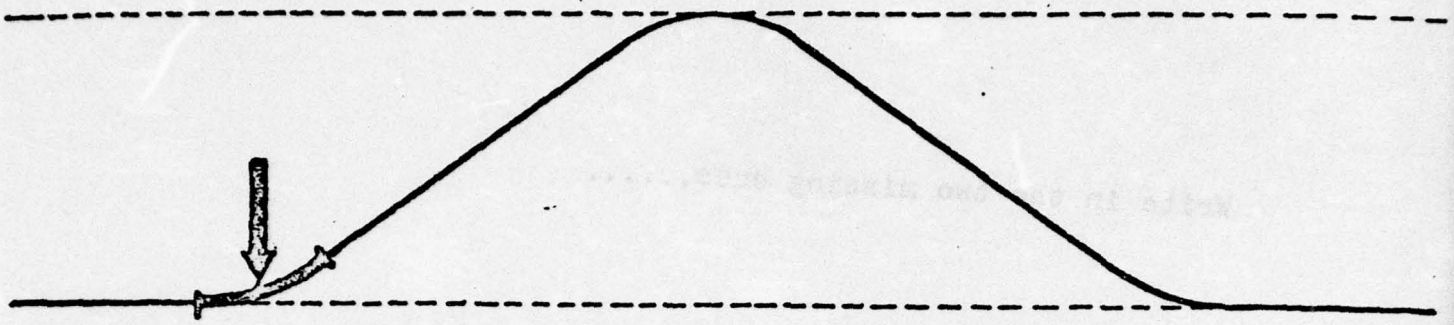
4. 94±1%

Write in the two missing cues.....

1. Lead with power
2. Pitch to maintain 160
3. _____
4. _____

Let's see whether you've got it all together now.

Write up the cues for this transition in their correct order.

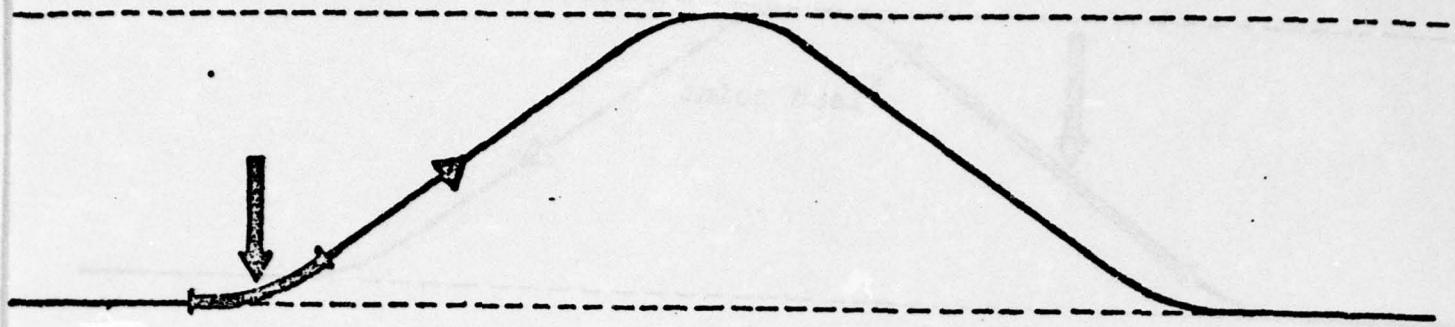


1. _____

2. _____

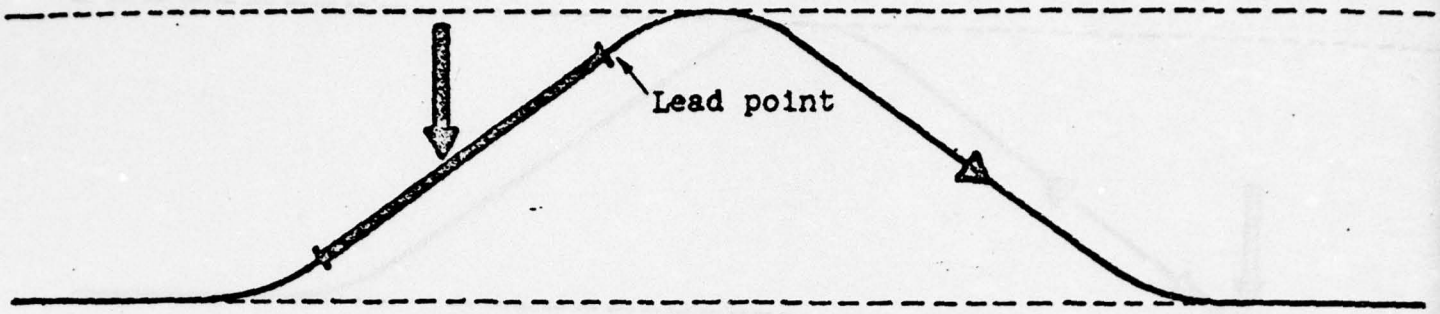
3. _____

4. _____

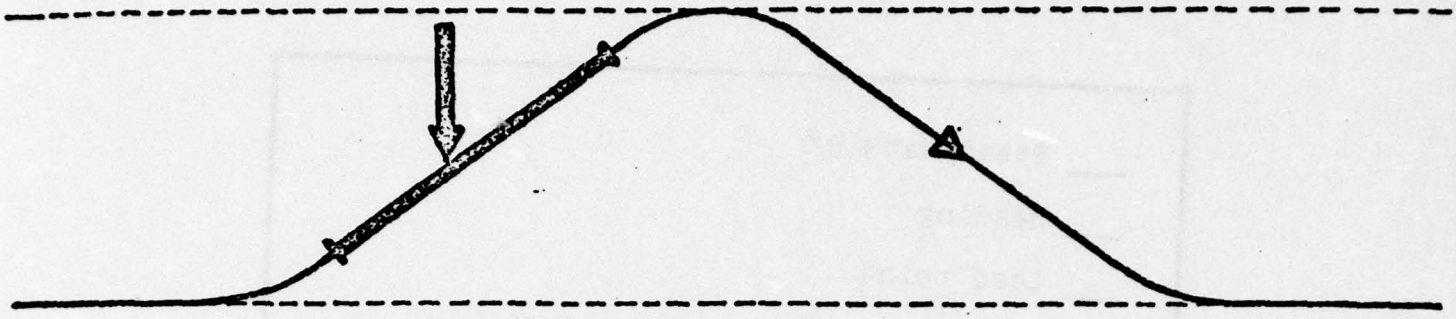


1. Lead with power
2. Pitch to maintain 160
3. +5°
4. 94±1%

Steady State Climb



Having accomplished a smooth transition, the task for the pilot is now to maintain a steady state climb at a constant vertical rate and of course, at a constant airspeed. To accomplish this, pitch must be held as stable as possible at the $+5^{\circ}$ mark. If the vertical velocity is off, small adjustments in pitch attitude will suffice. The width of the black lines on the attitude indicator is a good reference to use. If the airspeed is off, use small power changes for corrections. During the steady state climb is also the best time for checking your heading repeatedly. Use small amounts of both rudder and bank to correct. Watch out for the leadpoint to terminate the climb: 10% of the VVI indication = 100 ft prior to target altitude.



1. Steady at +5°
2. Vertical velocity - small pitch changes
3. Airspeed - small power changes
4. Heading
5. Leadpoint

Again: read and study this list carefully. Imagine yourself going through every step in the airplane. If you are not quite clear about one of these abbreviated cues, refer back to the previous page .

___ Steady at + 5°

___ Heading

___ Lead point

___ Airspeed - small power changes

___ Vertical velocity - small pitch changes

Unscramble by numbering correctly !

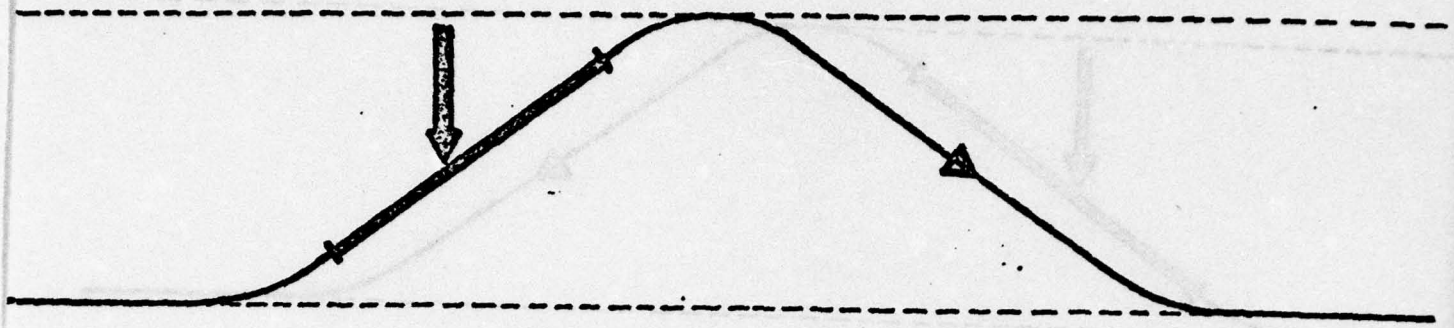
1. _____
2. Vertical velocity - small pitch changes
3. Airspeed - small power changes
4. _____
5. _____

Complete the list !

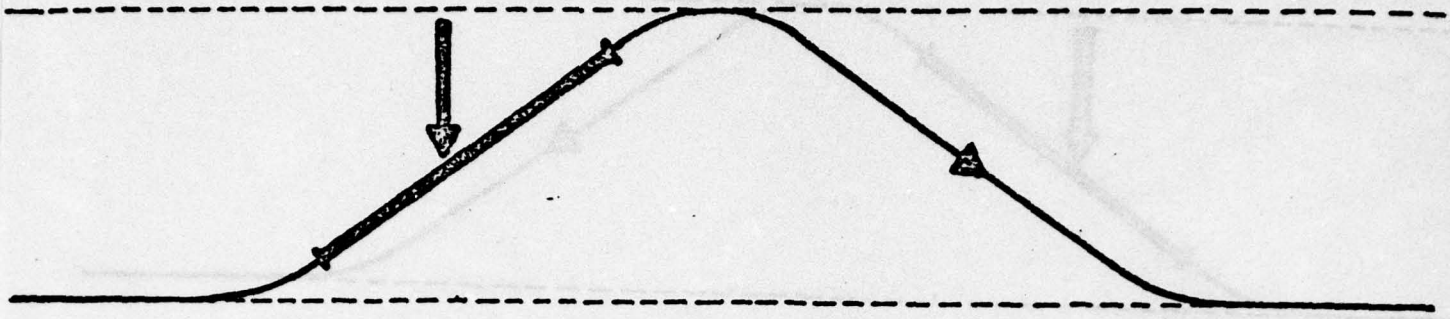
1. Steady at +5°
2. _____
3. _____
4. Heading
5. Leadpoint

Complete the list !

Write down all five cues for the climb ....

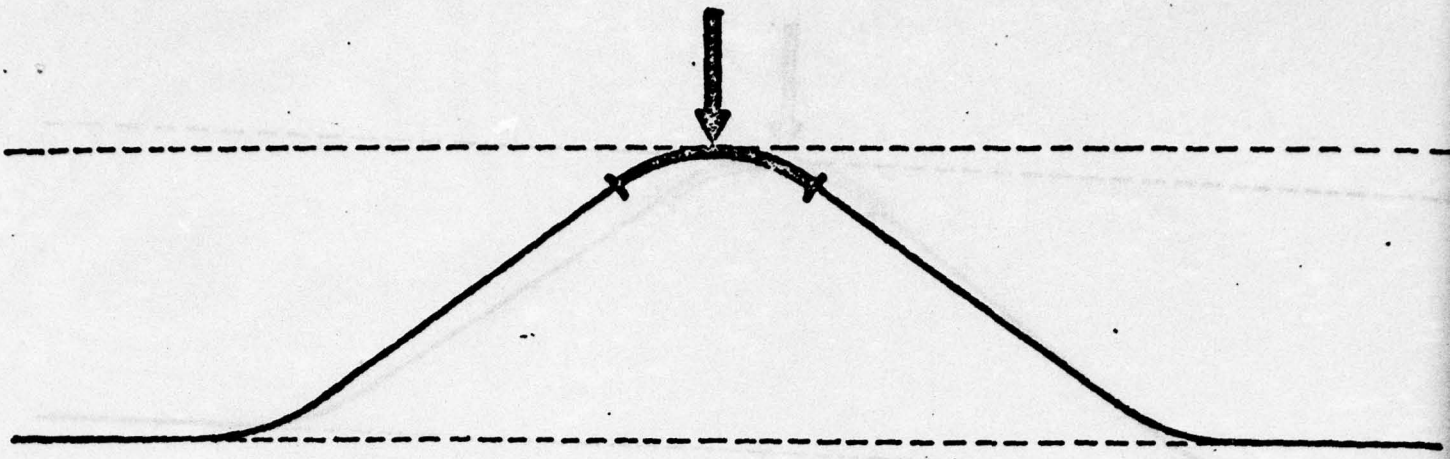


1. _____
2. _____
3. _____
4. _____
5. _____



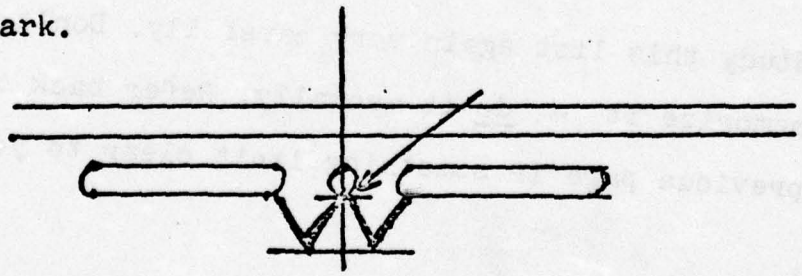
1. Steady at + 5°
2. Vertical velocity - small pitch changes
3. Airspeed - small power changes
4. Heading
5. Lead point

Transition II

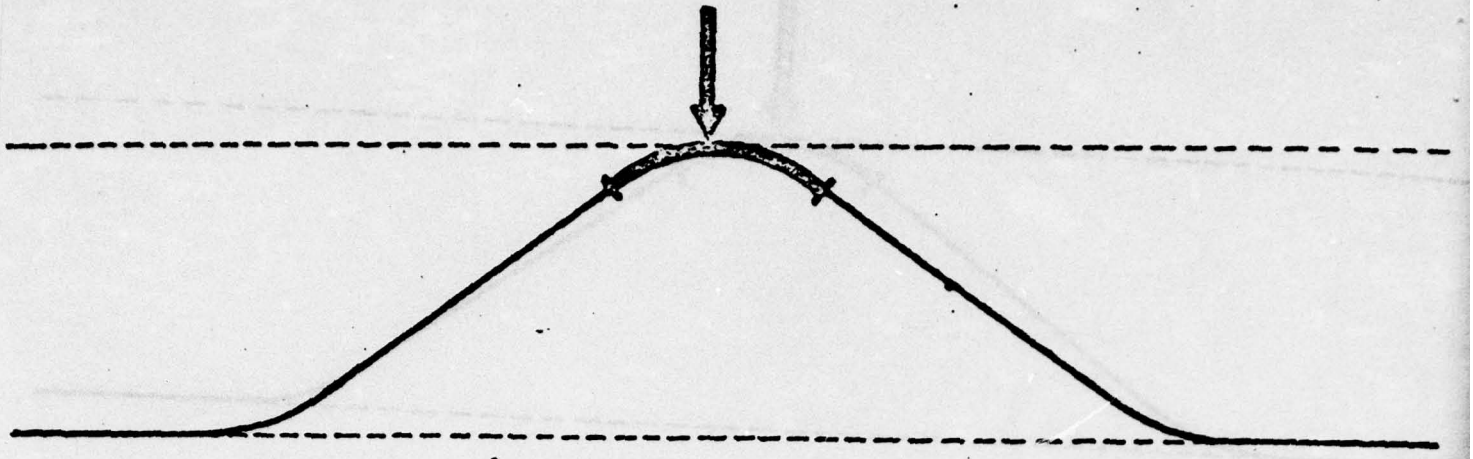


At the lead point start the transition over the top such that the aircraft peaks out at precisely 16000 feet. During this transition the vertical velocity changes from +1000 feet/minute to -1000 feet/minute.

Begin the transition by leading with a smooth and continuous power reduction. Match this power reduction by lowering your pitch smoothly and continuously so that the altimeter stops and reverses at 16000 feet. Continue to lower pitch until the bottom of the center dot touches the -5° mark.



Continue to reduce power until shortly after the gear warning horn comes on. Then check your airspeed and set power to 58%.



1. Reduce power
2. Match with pitch for 16000
3. Continue to -5°
4. Power past gear warning
5. Check for 160 at 58%

Study this list again very carefully. Don't just memorize it - <u>do</u> it mentally. Refer back to the previous page if something isn't clear to you.

___ Check for 160 at 58%

___ Reduce power

___ Power past gear warning

___ Match with pitch for 16000

___ Continue to -5°

Unscramble the list by numbering correctly !

Supply the missing cues ...

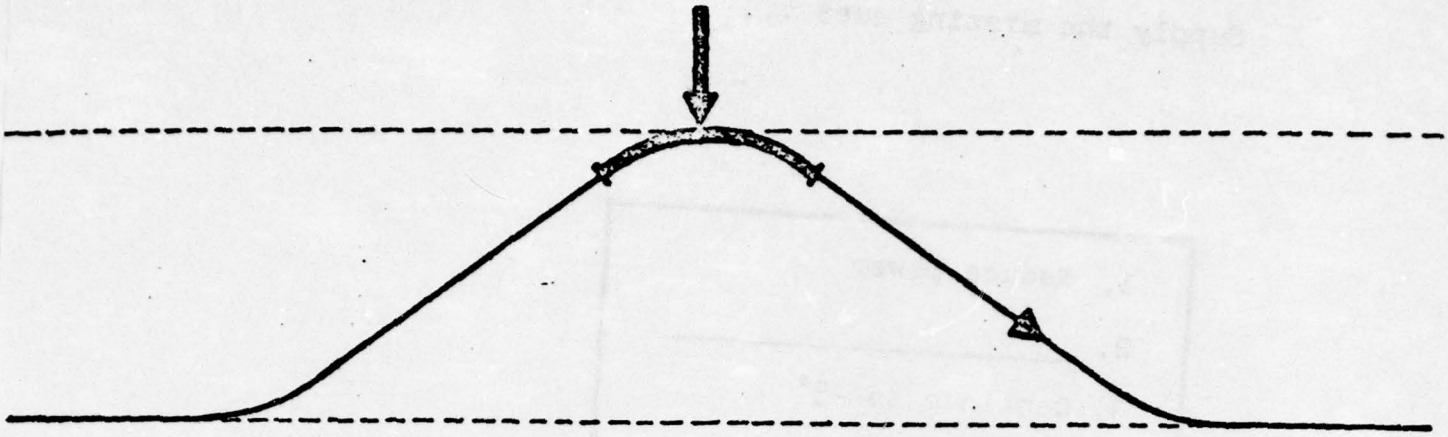
1. _____
2. Match with pitch for 16000
3. _____
4. Power past gear warning
5. Check for 160 at 58%

Supply the missing cues ...

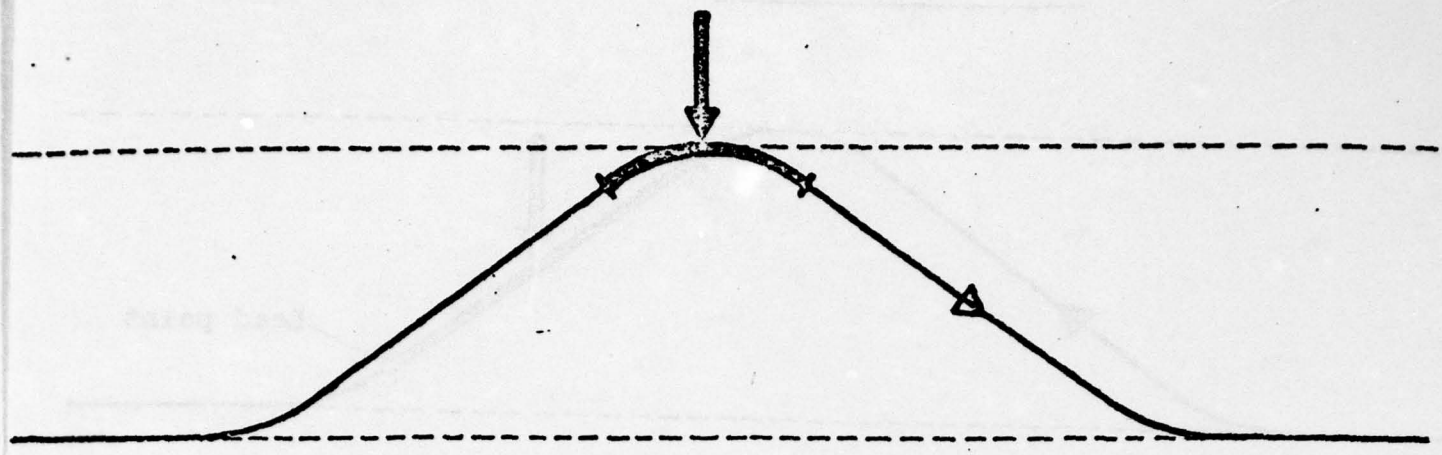
1. Reduce power
2. _____
3. Continue to -5°
4. _____
5. _____

O.K., all of the cues for the transition over the top...

Write them down please.

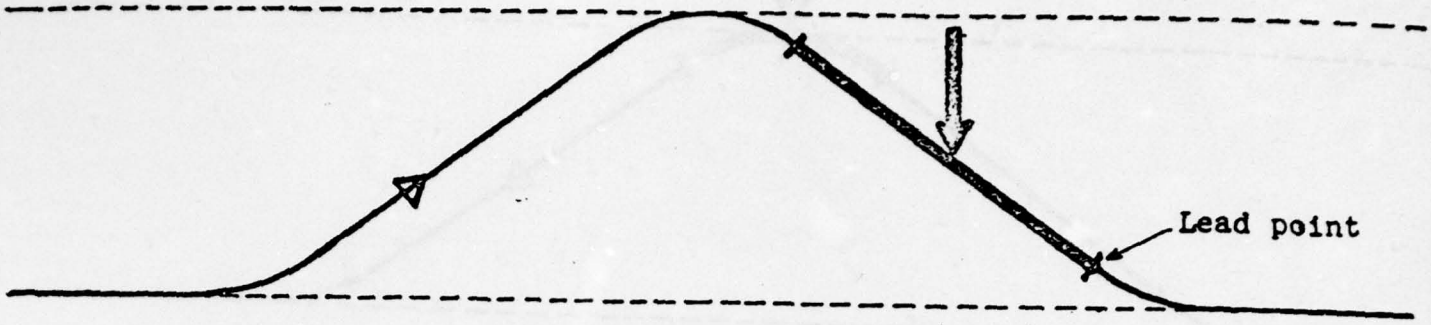


1. _____
2. _____
3. _____
4. _____
5. _____



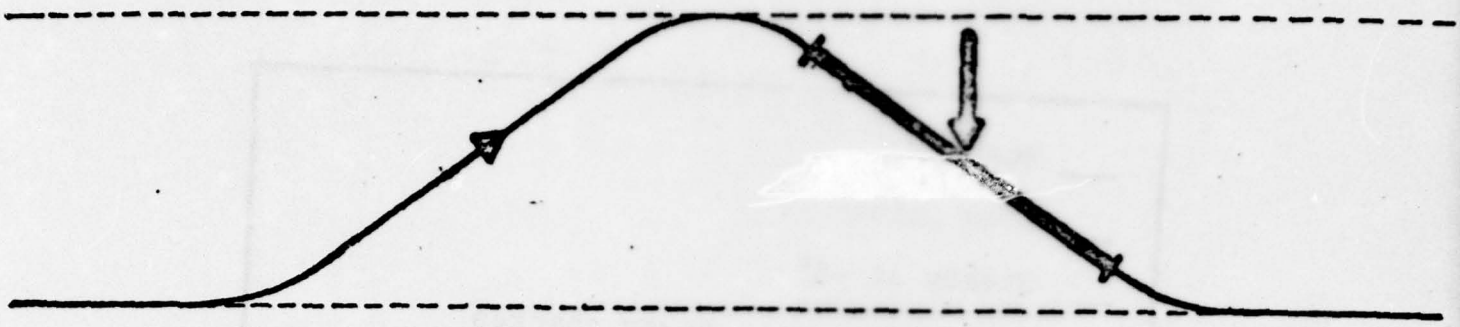
1. Reduce power
2. Match with pitch for 16000
3. Continue to $-5°$
4. Power past gear warning
5. Check for 160 at 58%

Steady State Descent



Maintaining a steady state descent amounts to doing essentially the same thing as during the climb.

Hold the pitch steady at -5°. Adjust for deviations in vertical velocity with small corrections on the attitude indicator. Correct for airspeed with small power inputs. Check your heading repeatedly (remember to use both rudder and stick). Watch out for the lead point: 10% of the VVI indication = 100 feet prior to starting altitude.



1. Steady at -5°
2. Vertical velocity - small pitch changes
3. Airspeed - small power changes
4. Heading
5. Lead point

Study this sequence carefully. Do it mentally!

Remember the reference for pitch changes.

Unscramble please .....

___ Heading

___ Lead point

___ Steady at -5°

___ Airspeed - small power changes

___ Vertical velocity - small pitch changes

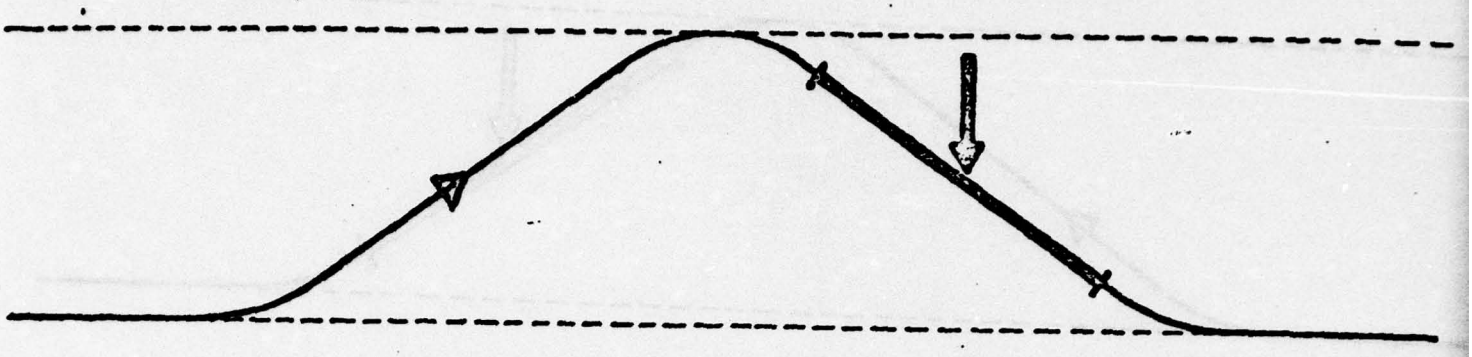
Complete the list

1. Steady at -5°
2. Vertical velocity - small pitch changes
3. _____
4. _____
5. _____

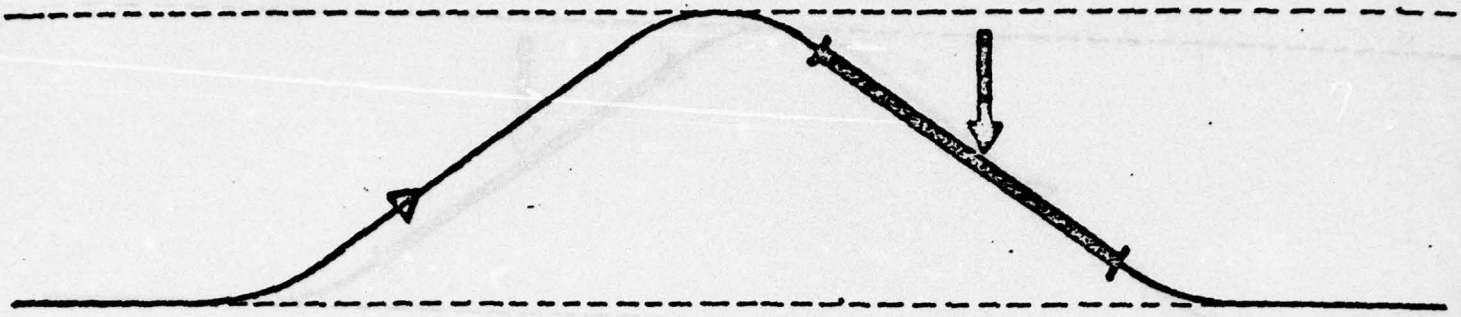
Complete the list

1. _____
2. _____
3. Airspeed - small power changes
4. Heading
5. Lead point

And as usual: write up all the cues for the descent segment

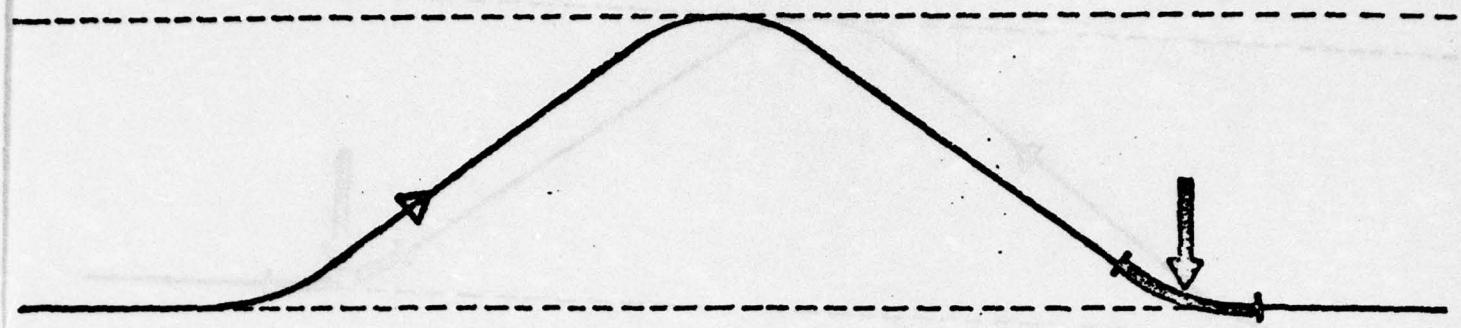


1. _____
2. _____
3. _____
4. _____
5. _____



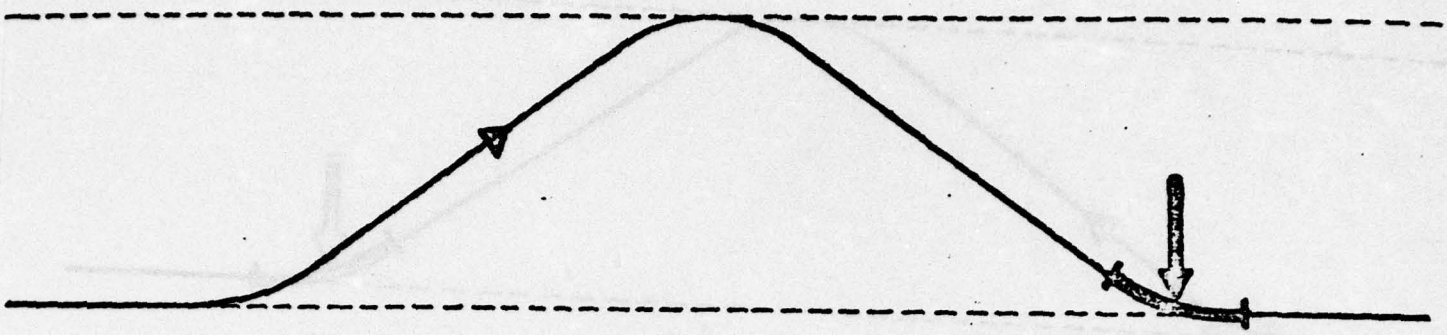
1. Steady at -5°
2. Vertical velocity - small pitch changes
3. Airspeed - small power changes
4. Heading
5. Lead point

Transition III



This transition concludes the maneuver. It is nothing else but a normal level-off from a descent at a prespecified altitude.

Lead by adding power with a smooth, continuous and fairly rapid movement. Raise pitch smoothly and gently so as to arrive at level indication when you reach 15000 feet. Hold level pitch and set power to 82±1%.



1. Lead with power
2. Level pitch at 15000
3. Hold level
4. 82±1%

Again, rather than just memorizing the list, imagine yourself going through the level-off in the airplane.

Unscramble the list

___ 82±1%

___ Level pitch at 15000

___ Lead with power

____ Hold level

Supply the missing cues

1. _____

2. Level pitch at 15000

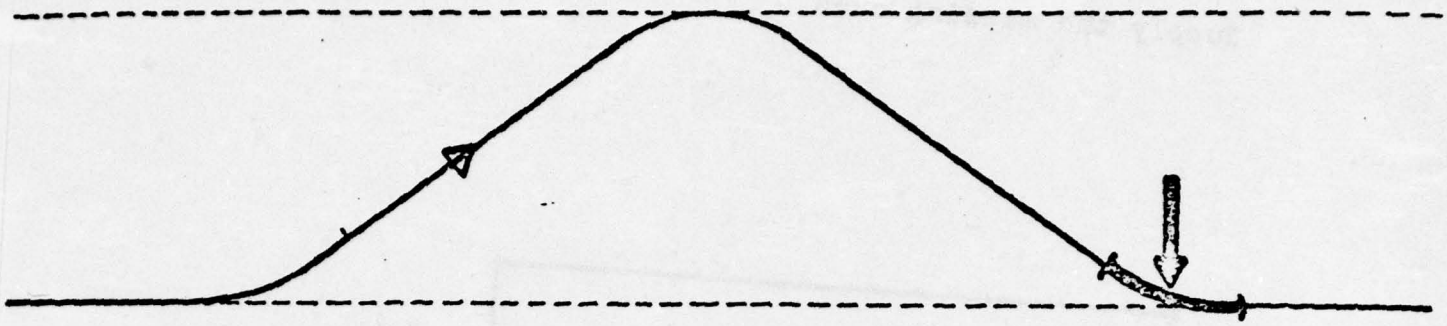
3. Hold level

4. _____

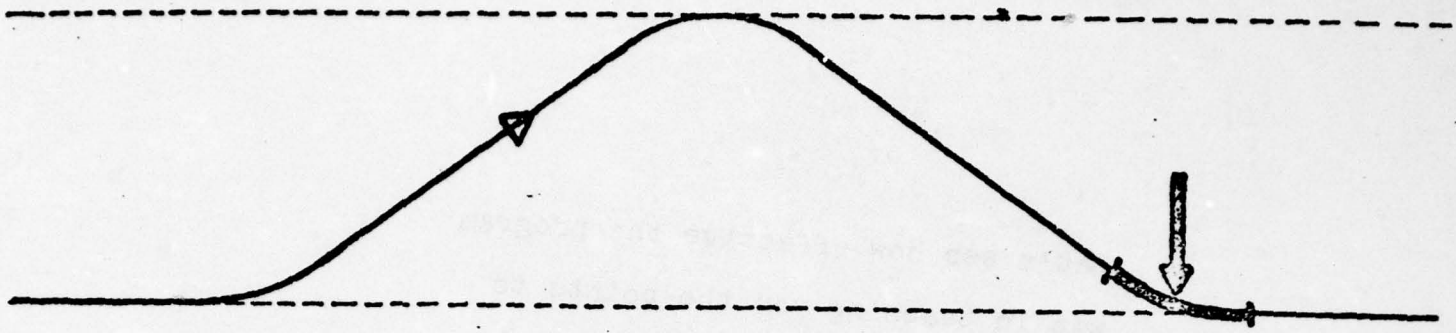
Supply the missing cues

1. Lead with power
2. _____
3. _____
4. 82±1%

Write out all the cues for the level-off



1. _____
2. _____
3. _____
4. _____



1. Lead with power
2. Level pitch at 15000
3. Hold level
4. 82±1%

Mark your finishing time for the program here: _____

Let's see how effective the program was in teaching you the points to watch out for when flying a Vertical S-A.

Turn to the next page and take the test.....

Good Luck !

Straight and Level

1. _____
2. _____
3. _____
4. _____

Transition I

1. _____
2. _____
3. _____
4. _____

Steady State Climb

1. _____
2. _____
3. _____
4. _____
5. _____

Transition II

1. _____
2. _____
3. _____
4. _____
5. _____

Test Page 2

Steady State Descent

1. _____
2. _____
3. _____
4. _____
5. _____

Level-off

1. _____
2. _____
3. _____
4. _____

Mark the time when you finished the test here: _____

Appendix G

Levels of Instructional Cues

Systematically developed cues

Straight and Level

1. Establish 160 and trim
2. Note power setting: 82 ± 1%
3. Level attitude indicator
4. Heading on top of J-2

Transition 1

1. Lead with power
2. Pitch to maintain 160
3. +5°
4. 94 ± 1%

Steady State Climb

1. Steady at +5°
2. Vertical velocity - small pitch changes
3. Airspeed - small power changes
4. Heading
5. Leadpoint

Transition 2

1. Reduce power
2. Match with pitch for 16000
3. Continue to -5°
4. Power past gear warning
5. Check for 160 at 58%

Steady State Descent

1. Steady at -5°
2. Vertical velocity - small pitch changes
3. Airspeed - small power changes
4. Heading
5. Leadpoint

Transition 3

1. Lead with power
2. Level pitch at 15000
3. Hold level
4. 82 ± 1%

Current operational cues

Straight and Level

1. Hold 160
2. Align J-2 compass
3. Check VVI
4. Level attitude indicator

Transition 1

1. Increase pitch and Power: 1¼ and 94 ± 1%
2. Maintain 160
3. VVI: + 1000 ft/min
4. Wings level

Steady State Climb

1. When stable check VVI
2. Fine tune for 1000 ft/min
3. Power for 160
4. Trim
5. Heading

Transition 2

1. 30 - 45 sec: Lead point
2. Lower nose 2½ bar widths
3. Reduce power to maintain 160
4. VVI: -1000 ft/min
5. Wings level

Steady State Descent

1. Check tachs
2. Maintain 160
3. Slow changes
4. Trim
5. Heading

Transition 3

1. Lead point
2. Level pitch
3. Increase power
4. Wings level

Appendix H

Program Changes during Formative Phase

Changes on the basis of tryout #1 and tryout #2

1. Feedback added after each response.
2. Immediate posttest added (as last two pages).
3. Lead point marked and labelled in expository frames for the second and third transition segment.
4. Corrected one SC, Straight and Level, #2 to 82 ± 1% (instead of 81 ± 1%).
5. Changed 93 ± 1% to 94 ± 1%.
6. Corrected typographical error on p. 3 (15000 feet).
7. Added direction arrows in latter part of program.
8. Checked and marked the degrees of pitch.
9. Eliminated "funny" remark on bottom of p. 25.
10. Repaginated.

Changes on the basis of tryout #3

1. Eliminated pagination.
2. Corrected typographical errors.
3. Inserted blue pages after each student response.

Appendix I

Experimentor - Subject Communications

Communications between Experimentor and Subject during the simulator phase:

1. Preparation:

   a. After both Experimentor and Subject have put on headsets a standard USAF communications check is accomplished.

   b. Experimentor: "Adjust your rudder pedals."

   (Subject adjusts pedals).

   Experimentor: "The simulator is now in the FREEZE condition. I will now unfreeze the simulator and you take control."

   (Experimentor unfreezes simulator).

   Experimentor: "You have it." (Experimentor closes canopy). "Establish straight and level flight at 15000', 160 knots and 360° of heading. This simulator is very sensitive. You need to use a very light touch. Three fingers will do it. When you have established straight and level flight you will fly the Vertical S-A six times. In between each Vertical S-A you will fly straight and level for one minute. I will tell you when to start a Vertical S-A, you will tell me when you are finished with the maneuver, that is when you come back down to 15000 feet. Any questions?" (Experimentor then answers questions if they pertain to procedure. Other questions are ignored.)

2. Recording phase:

   Experimentor: "Start five minutes straight and level now."

   Experimentor: "Three minutes are up, two more to go."

Experimentor: "Start your first Vertical S-A now."

Subject: "Finished now."

Experimentor: "O.K., fly straight and level for one minute."

Experimentor: "Start your second Vertical S-A now."

etc. to trial #6.

Subject Master Sheet

E

154

Name: BARKER, T.		Age: 26	
Group:	E	Prior Experience: 0 Not formally rated, but considerable	
Running #:	9		
Date:	3/7	T-37 hours: 9.5	
Time in:	09:01	Solo: No	
Time out:	10:25	T-4 hours: 1 mission 1.5	
Time elapsed:		Last trainer mission: 2101	

PRETRAINING

In Program Errors		Start	09:03
Time through program	:23	Finish	09:32
Posttest Errors		Elapsed time:	
Time through posttest	—		
Percent correct			
Error Rate			

SIMULATOR

Total elapsed time forgot / ~ 25

Elapsed times for trials				
09:35 09:39 10:05	1	2:18	4	2:17
	2	1:59	5	2:07
	3	2:05	6	3:+

Protocol remarks

PROTOCOL SHEET

Name	Group	Number	Date
BARKER/J.B.	E	9	3/7

Time in 0901 Time out 10.25

STUDY PHASE 0903 in bottle / 0932 out of bottle
Warned to wait after finishing booklet until E got him.

Went to take a leak between study & sim phases.

SIMULATOR PHASE 0935 / 0939 /

1. 2+
2. 1:15
3. 1:01
4. 1:16
5. 1:00
6. 1:15

Didn't know for sure whether he should maintain alt of the indications he ended up with after trial 1 or with them set in their original conditions. Was duly instructed.

Comment by student: Finding the correct power setting was the trickiest.

GENERAL

from Pensacola, Fla, talks with a real nice drawl. Flies a lot for a hobby. Commercial pilot uncle flies and gives him rides. "I've been around flying all my life." Hard to judge what influence this may have. His dad was both a civilian & military pilot. Homegrown + USAF officials.

Performance was good.

Appendix K

Questionnaire

POST INSTRUCTION QUESTIONNAIRE

Name: _____
(please print)

1. In your opinion, what is the most important cue for the whole maneuver?

_____

_____

2. . . . for the transitions?

_____

_____

3. . . . for the constant rate climb/descent?

_____

_____

4. Describe or list the cues or the procedure you used for the transition over the top.

_____

_____

_____

_____

_____

5. Which of the cues you learned (or generated) during the study phase was most helpful in flying the maneuver?

_____

_____

6. Which part or aspect of the maneuver was the hardest?

_____

_____

7. Did you use trim during the constant rate climb or descent?

YES NO

8. What is the best pitch reference you can use during the maneuver?

_____

9. If you had your choice, which instructional procedure would you prefer in order to prepare for flying?
(Number in order or preference)

Selfstudy only
Selfstudy plus briefing by IP
Briefing by IP only
Programmed Instruction
Programmed Instruction plus briefing by IP

10. How would you rate the instruction you received during the study phase?
(Circle the number which corresponds most closely to your impressions)

	Low				High
Usefulness in terms of helping you to perform the maneuver	1	2	3	4	5
Thoroughness Completeness	1	2	3	4	5
How useful were the drawings?	1	2	3	4	5
Indicate how well you liked the materials	1	2	3	4	5

11. Which is harder to fly

the simulator used in the experiment
the regular simulator
the aircraft?

(check one)

12. Any particular comments about the simulator?

13. Any comments about the study environment?

14. Any other comments, remarks, suggestions?

We thoroughly appreciate your cooperation in this research effort. There is one more very important thing we would like to ask of you:

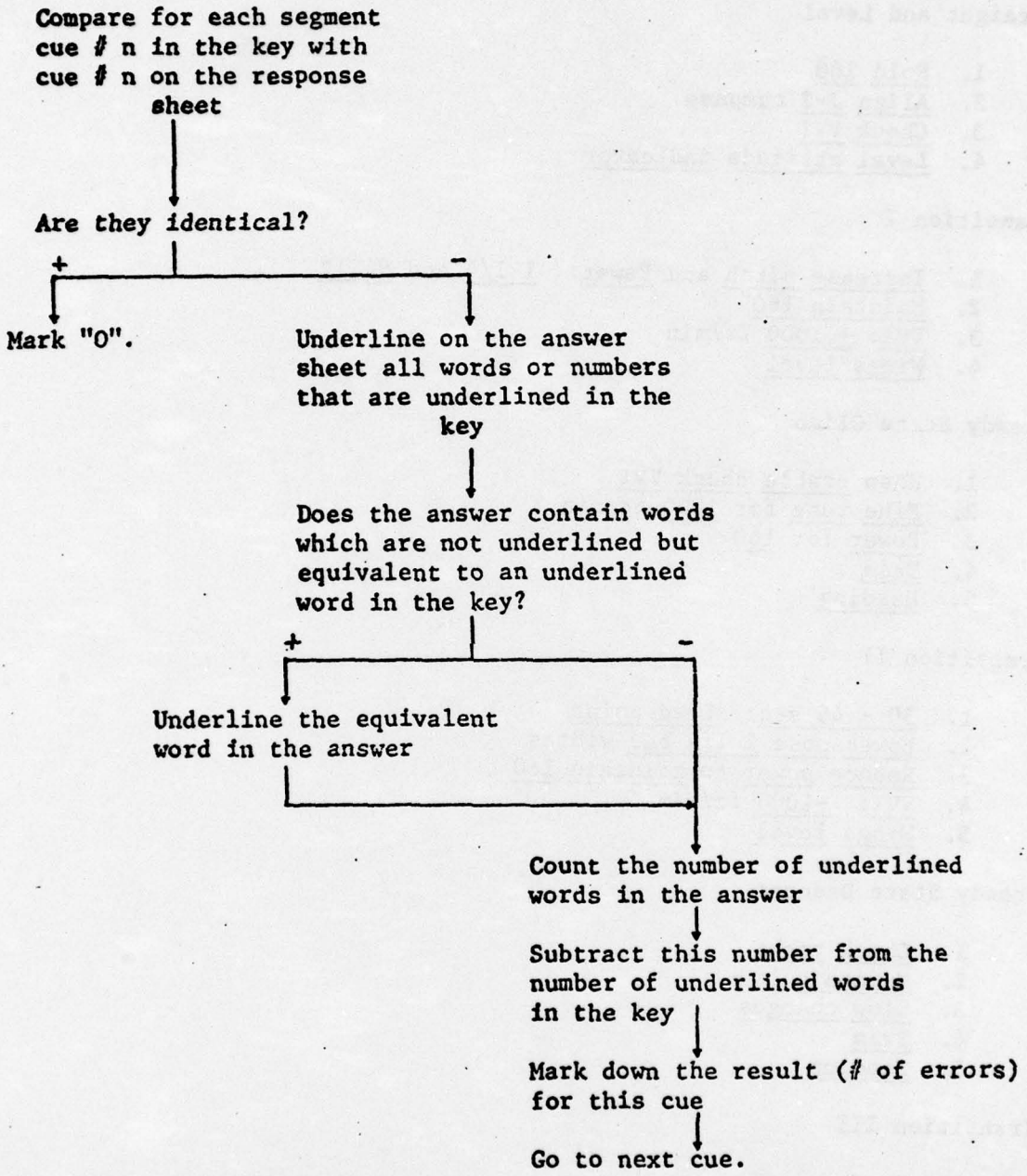
DO NOT TALK TO YOUR CLASSMATES ABOUT THE TRUE NATURE OF THE EXPERIMENT FOR THE NEXT THREE WEEKS!

Prior information may produce extreme distortions of the results. If you are asked, please answer by saying that a research team from ASU is experimenting with some new performance measurement techniques. The participants are merely asked to fly a profile given over RT (this is quite close to the truth!).

Appendix L

Scoring Algorithm and Keys

Scoring Algorithm



Scoring Key for groups 1 and 2: Current Operational Cues

Straight and Level

1. Hold 160
2. Align J-2 compass
3. Check VVI
4. Level attitude indicator

Transition I

1. Increase pitch and Power: 1 1/4 and 94±1%
2. Maintain 160
3. VVI: + 1000 ft/min
4. Wings level

Steady State Climb

1. When stable check VVI
2. Fine tune for 1000 ft/min
3. Power for 160
4. Trim
5. Heading

Transition II

1. 30 - 45 sec: Lead point
2. Lower nose 2 1/2 bar widths
3. Reduce power to maintain 160
4. VVI: -1000 ft/min
5. Wings level

Steady State Descent

1. Check tachs
2. Maintain 160
3. Slow changes
4. Trim
5. Heading

Transition III

1. Lead point
2. Level pitch
3. Increase power
4. Wings level

Scoring Key for groups 3 and 4: Systematically developed cues

Straight and Level

1. Establish 160 and trim
2. Note power setting: 82 ± 1%
3. Level attitude indicator
4. Heading on top of J-2

Transition I

1. Lead with power
2. Pitch to maintain 160
3. +5°
4. 94 ± 1%

Steady State Climb

1. Steady at +5°
2. Vertical velocity - small pitch changes
3. Airspeed - small power changes
4. Heading
5. Lead point

Transition II

1. Reduce power
2. Match with pitch for 16000
3. Continue to -5°
4. Power past gear warning
5. Check for 160 at 58%

Steady State Descent

1. Steady at -5°
2. Vertical velocity - small pitch changes
3. Airspeed - small power changes
4. Heading
5. Lead point

Transition III

1. Lead with power
2. Level pitch at 15000
3. Hold level
4. 82 ± 1%