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This report reviews a theoretical framework and empirical research concerning the interactions between cognitive abilities (both general intellectual and perceptual speed) and self-regulatory/metacognitive processes (including emotion control and motivation control) during complex skill acquisition. The framework outlines how ability and metacognitive strategies affect attention and cognitive effort as determinants of individual and group differences in task performance during skill acquisition. Specifically, the self-regulatory strategy of emotion control affects task performance early in skill acquisition, when attentional resource demands are the highest . Conversely, the self-regulatory strategy of motivation control affects task performance late in skill acquisition, when attentional resource demands are diminished. Individual differences in general ability interact with the dynamic attentional demands of complex tasks during training, and thus further interact with the influence of these two self-regulatory strategies. Two experiments delineating the interactive effects of training for emotion control and motivation control were conducted,
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with a criterion air traffic controller simulation task. The first experiment demonstrated the costs and benefits of embedded training of self-regulatory skills during complex skill acquisition. The second experiment demonstrated costs and benefits of pretraining of self-regulatory skills on a criterion transfer task. Overall, training of emotion control skills was shown to be beneficial to lower-ability learners, and training of motivation control skills was shown to be beneficial to higher-ability learners. In addition, self-regulatory training was demonstrated to impact task performance strategies, such as overall activity level, and speed/accuracy. Implications for future investigations are discussed, along with the potential for interventions to optimize training of lower and higher-ability learners.

Ability and Metacognitive Determinants of Skill Acquisition and Transfer

FINAL REPORT
(Period 1/1/89 - 4/30/90)

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SUMMARY

This report reviews a theoretical framework and empirical research concerning the interactions between cognitive abilities (both general intellectual and perceptual speed) and self-regulatory/metacognitive processes (including emotion control and motivation control) during complex skill acquisition. A general background for the merging of ability and motivational approaches to skill acquisition is presented, using the construct of cognitive/attentional effort. The combined ability/motivational theory is presented, along with a delineation of self-regulatory processes and metacognitive strategies for task engagement during learning. Two empirical experiments using a simulated air traffic controller task are described, and the results are presented in detail. The first experiment demonstrated the costs and benefits of embedded training of self-regulatory skills during complex skill acquisition. The second experiment demonstrated costs and benefits of pretraining of self-regulatory skills on a criterion transfer task. Overall, training of emotion control skills was shown to be beneficial to lower-ability learners, training of motivation control skills was shown to be beneficial to higher-ability learners. In addition, self-regulatory training was demonstrated to impact task performance strategies, such as overall activity level, and speed/accuracy. This series of investigations is part of an ongoing research program that seeks to unify ability and self-regulatory determinants of individual and group differences in skill acquisition. The interactive effects of ability and motivation are discussed within a skill-training perspective for self-regulatory/metacognitive processes. The potential implications of tailored training based on remediation/enhancement of self-regulatory skills are discussed, with respect to future research and possible impact on extant training programs.

PREFACE

This research was sponsored by the Air Force Office of Scientific Research and Project LAMP, under the auspices of the Air Force Human Resources Laboratory (contract AFOSR-89-0242) to R. Kanfer and P. L. Ackerman. This research investigated the effects of individual differences in abilities, motivational, and metacognitive processes, and task demands during skill acquisition using a theoretical framework that permits examination of the simultaneous effects of these factors on performance. The authors would like to gratefully acknowledge Kim Pearson for his programming assistance, the cooperation of the Project LAMP in supervising the collection of the data reported here, including Dr. William C. Tirre, Dr. Dan J. Woltz, and Dr. Patrick C. Kyllonen.

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ABILITY AND METACOGNITIVE DETERMINANTS OF SKILL ACQUISITION AND TRANSFER

I. INTRODUCTION

The purpose of this research is to investigate the independent and interactive effects of metacognitive/motivational processes and cognitive ability determinants of individual differences as they pertain to skill acquisition and transfer-of-training. In this research program two disciplines are employed to provide a unified approach to the motivational and cognitive ability determinants of skill learning. Specifically, this program of research is based on: (1) A theory of the cognitive determinants of individual differences in skill acquisition (Ackerman, 1986, 1987, 1988, 1989; and (2) A theory of the motivational/ metacognitive determinants of learning and performance (Kanfer, 1987, in press, Kanfer & Paullin, 1986). The unified approach provides a framework that delineates how task demands, motivation, and critical cognitive abilities interact in determining individual differences in initial performance, rate of learning, and asymptotic skilled performance on complex tasks.

Previous research using the integrated model, supported by AFOSR/AFHRL Project LAMP (for reports of the research, see Kanfer & Ackerman, 1989(a), 1989(b), Ackerman & Kanfer, 1989) provides support for the integrated theory and demonstrates the simultaneous influence of ability and motivational factors during learning. The research completed under this grant extended this program of research to investigate specific motivational and information-processing conditions that attenuate or exacerbate individual differences during learning and transfer-of-training. This investigation provided further elaboration of a rubric for ultimately increasing the precision of measures to assess individual differences in learning abilities in the context of particular training methods.

II. GENERAL BACKGROUND

The theoretical foundation for the proposed research lies in cognitive, information-processing psychology. In particular, the construct of "cognitive resources" or "attentional resources" provides a heuristic linkage between ability and motivation and clarifies the influence of task characteristics on the ability/motivation-performance relations. The fundamental components of the integrated resource theory (Kanfer & Ackerman, 1989(a), 1989(b) are presented briefly below.

<u>Attention as a Core Construct</u>. The construct of cognitive or attentional resources can be used to link ability and motivation constructs. In addition, this construct clarifies the influence of objective task characteristics on the ability/motivation - performance relations.

Theories of human attention (e.g., Kahneman, 1973; Norman & Bobrow, 1975; Wickens, 1984) define attentional effort as cognitive resources of limited availability. A central concern for such theories is to understand the effects of various task characteristics on the relationship between attentional effort and task performance. The performance-resource function postulated by Norman and Bobrow (1975) provides a conceptual metric for effort-performance relations under a variety of information-processing constraints, such as task difficulty. Norman and Bobrow proposed the performance-resource function based upon the concepts of "resource limitations" and "data limitations." Resource limitations refer to performance limits due to the amount of cognitive resources devoted to the task. Data limitations refer to the performance limits imposed by task characteristics. The performance-resource function describes the relationship between the amount of cognitive/attentional resources devoted to a task and the resulting level of performance on that task. The only explicit assumption about these functions is that they are monotonically increasing; that is, performance will not decrease when additional resources are devoted to the task.

From this perspective, a task is resource limited when increases or decreases in the amount of attention devoted to the task result in measurable changes in objective task performance. Conversely, a task is said to be data limited when changes in the amount of attention do *not* result in substantial changes in performance. Thus, attention demands associated with a task may be classified to indicate performance-resource functions that show tasks to be *dependent* upon, or *insensitive* to, changes in attentional effort devoted to the task.

Attention research has indicated that the performance-resource function is altered under several key situations (e.g., Norman & Bobrow, 1975; Wickens, 1984). Changes in task difficulty, for example by increasing the load on memory, are associated with increasing resource dependence. Conversely, when the task is simplified, the slope of the performance-resource function decreases (the task becomes more resource-insensitive). Similarly, under conditions of skill acquisition, a task that is initially resource-dependent will ordinarily become progressively more resource-insensitive with task practice (Fisk & Schneider, 1983). As **Figure 1** indicates, task practice is associated with higher levels of performance *and* decreasing demands on attention (adapted from Norman & Bobrow, 1975).

Skill Acquisition and Attention. Learning theorists have historically described skill acquisition in terms of stage or phase designations delineating different aspects of the learning process (Adams, 1987; Anderson, 1982, 1983; Fitts, 1964; Fitts & Posner, 1967, Shiffrin & Schneider, 1977). Anderson (1982, 1983) for example, has used a "production system" perspective to suggest that skill acquisition can be segmented into three phases: "Declarative Knowledge" (Phase 1), followed by "Knowledge Compilation" (Phase 2), and finally, "Procedural Knowledge" (Phase 3).

Phase 1 - Declarative Knowledge. Declarative knowledge is defined as "knowledge about facts and things" (Anderson, 1985, p. 199). The *declarative knowledge* phase appears to involve all of the requisite memory and reasoning processes that allow the learner to attain an "understanding" of the task requirements. The task content at this point often consists of the specification of task objectives (i.e., some end result of proficiency or task completion) and frequently includes instruction about the task, as would be exemplified by a lecture on a mechanical system or general principles for equipment operation. During this phase the performer may observe demonstrations of the task, may encode and store task rules, and may derive strategies for the task.

A critical feature of the declarative phase of skill acquisition is the substantial attentional resource demands imposed on the learner. At this level of skill acquisition, persons devote most, if not all of their attention to understanding and performing the task. When confronted with additional information processing requirements, as with the inclusion of a secondary task, learners are unable to adequately devote attention to the secondary task *and* to the learning of the criterion task simultaneously (e.g., see Nissen & Bullemer, 1987). Performance in the declarative knowledge phase is slow and error prone. Once the learner has come to an adequate declarative representation of the task, he/she can proceed to the second stage -- the *knowledge compilation* phase.

Phase 2 - Knowledge Compilation. For tasks that allow for consistent information processing, speed and accuracy markedly improve over the course of practice (Fisk, Ackerman, & Schneider, 1987). During the *knowledge compilation* phase of skill acquisition, persons integrate the sequences of cognitive and motor processes required to perform the task. As various methods for simplifying or streamlining the task are tried and evaluated, performance generally becomes faster and less error-prone than in the declarative knowledge phase. Anderson (1985) indicates that the process of knowledge compilation is analogically similar to the process of compiling interpretive computer source code (the actual program statements) to obtain object code (or machine-level code). As this compilation occurs for each task component, the declarative knowledge system (i.e., the attentional apparatus) is relieved of the processes originally required to perform the task. As such, the attentional load on the learner is reduced as the task objectives and procedures are moved from short-term or working memory, to long-term memory (Fisk & Schneider, 1983).

When a competing task is added to the learning task during the knowledge compilation phase, performance on the learning task may not improve to the same degree as under single task conditions, but learning task performance appears to be less susceptible to interference from external attentional demands (Yeh & Schneider, 1985). Therefore, attentional resources may be diverted from the task, or used for processing other components of the entire skill, without the resulting substantial decrements associated with removal of attention when the learner is at the declarative knowledge phase of skill acquisition.

Phase 3 - Procedural Knowledge. Procedural knowledge is defined as "knowledge about how to perform various cognitive activities" (Anderson, 1985; p. 199). This final phase of skill acquisition is reached when the individual has essentially automatized the skill and the task often can be efficiently performed with little attention. During Phase 3, the skill has been proceduralized such that once a stimulus is presented, the responses can often be prepared and executed without conscious mediation by the learner. After a substantial amount of consistent task practice, skilled performance becomes fast, accurate, and the task can often be performed with minimal impairment while attention is also being devoted to a secondary task (e.g., Schneider & Fisk, 1982). Although improvements in performance during practice are still found at this final level of skill acquisition, practice functions at this stage are well described in terms of diminishing returns, in keeping with the power law of practice (Newell & Rosenbloom, 1981).

Summary. From a performance-resource function perspective, information processing that requires the use of declarative knowledge implies analogous demands for attentional resources. During the first phase of skill acquisition, great demands are placed for cognitive/attentional effort. However, as a learner acquires skills (through knowledge compilation and proceduralization), the demands on the attentional system are markedly reduced, freeing resources for other activities. At asymptotic levels of skill acquisition (complete proceduralization), the task can often be performed with few attentional resources. This level of skilled performance is characterized as "automatic." Thus, when tasks demand the use of declarative knowledge, performance is essentially resource-dependent. As the skill is proceduralized, performance becomes resource-insensitive.

Attentional demands associated with phases of skill acquisition provide a conceptual framework for describing the influence of individual differences in ability and volition on task performance. The coordination of Ackerman's (1988) theory of individual differences in skill acquisition with the attentional framework is described below.

Cognitive Ability Determinants of Skill Acquisition. The theory of abilities and individual differences in skill acquisition formulated by Ackerman delineates the correspondence between cognitive abilities and normative phases of skill acquisition. Details are provided elsewhere (Ackerman, 1987, 1988, 1989), but the basic theory principles and mappings are provided below.

Ackerman (1984, 1986, 1987) suggested that individual differences in general intellectual ability may be conceptualized as differences in individuals' total attentional/cognitive capacity. Thus, the performance-resource function designation may be translated into a "performance-ability function." Given a direct equating between a subject's general intellectual ability and his/her level of attentional functioning (e.g., see Ackerman, 1987; Zeaman, 1978), individual differences in ability may be translated into individual differences in attentional resources. The resource demands of a task, and the relations between resources and performance may be thus mapped onto the relations between abilities and performance. From this perspective, resource-dependent tasks are anticipated to be "ability-dependent" and resource-insensitive tasks are similarly expected to be "ability-insensitive."

From an ability perspective, differences in task performance attributable to amount of attention allocated to the task are posited to be analogous to differences in performance attributable to individual differences in level of cognitive ability/ intelligence. In addition, there must be a correspondence between the attentional requirements of information processing tasks and the degree of association between general intellectual abilities and task performance (e.g., see Kyllonen, 1987).

The resource approach suggests that attentional/cognitive resources can be conceptualized as an amorphous pool, representing the limited capacity of the human's information processing system. Individual differences in ability are reflected in differences in total resource capacity. Consistent with previous findings (Ackerman, 1986, 1987), general ability - performance relations should be highest in the early, or declarative, stage of skill acquisition, and decline over the course of task practice. When resource demands attenuate, such as with skill acquisition, there is a decline in the role of general cognitive/intellectual abilities in determining individual differences in performance. Similar findings have been demonstrated from an alternative perspective, by Woltz (1988), and by Kyllonen & Woltz (1989).

Motivational/Metacognitive Determinants of Performance. Motivation refers to: (a) the *direction* of attentional effort; (b) the *proportion* of one's total attentional effort directed to the task (intensity), and (c) the extent to which attentional effort toward the task is *maintained over time* (Campbell & Pritchard, 1976; Humphreys & Revelle, 1984; Kanfer, 1987, in press; Naylor, Pritchard, & Ilgen, 1980). From a resource perspective, motivation is defined as the set of processes underlying the volitional allocation of limited cognitive resources, or attentional effort. This definition of motivation emphasizes metacognitive processes, or the self-regulation of cognitive resources, and allows us to recast motivational phenomena into an integrated information-processing resource-allocation framework.

Kanfer (1987, in press) has suggested that motivation affects learning and task performance through its influence on two distinct resource-allocation processes. Distal resource-allocation processes guide the establishment of an individual's behavioral intentions and choice among goals. Learners develop specific intentions (e.g., to learn a specific skill) and choose behavioral objectives (e.g., to obtain a specific performance score). The resource allocation processes underlying the development of these conscious intentions and goals are termed *distal*, because their effects on performance are indirect and depend on how the intentions and goals are implemented during learning.

Research on the effects of distal motivational processes has emphasized prediction of the effects of motivation on intended effort rather than the effects on skill acquisition or task performance per se (Locke, 1968; Mitchell, 1982; Vroom, 1964). As a result, information-processing demands of the task, individual differences in abilities, and other self-regulatory processes that may mediate the intention - performance relation have previously been neglected in these formulations.

When a learner's goals are readily attainable or anticipated to be easily achieved, goal choices made through the distal motivational system are typically realized quickly and without difficulty. However, when goals involve complex or novel learning, goal attainment typically requires additional volitional, or metacognitive activity to guide resource allocations during skill acquisition. The second source of motivational effects on skill acquisition stems from resource-allocation processes that occur *during* learning. These motivational processes are termed *proximal* since their operation has direct consequences for learning and goal attainment. Such motivational processes include metacognitive knowledge and the self-regulatory activities by which the learner directs, energizes, and sustains attentional effort for the purpose of learning. Whereas distal allocation processes influence the learner's decision to exert effort, proximal motivational processes operate in the context of competing demands for attentional effort imposed by the task and limitations of resource availability attributable to individual differences in ability. Metacognitive knowledge and self-regulatory activities can have a direct effect on rate and asymptotic level of skill acquisition. Proximal motivational processes that promote greater allocations of attentional effort to task components facilitate skill acquisition.

The resource allocation approach to motivation permits a distinction between motivational processes affecting an individual's decision to exert effort (distal) and the volitional processes by which intentions are translated into performance (proximal). Distal motivational processes typically occur prior to, or following task engagement. In contrast, metacognitive and self-regulatory processes *operate within the context of attentional demands imposed by the task and constraints on total resource availability.* Proximal resource allocation processes occur during learning and thus may affect performance through their effects on skill acquisition and effort.

An important implication of the distinction between distal and proximal motivation processes pertains to understanding how metacognitive processes and self-regulation affect skill acquisition. A number of studies demonstrate the beneficial consequences of self-regulation -- increased effort (i.e., increases in the total proportion of an individual's resource capacity devoted to the activity) and/or focusing a greater proportion of allotted resources to on-task activities in well-learned tasks (see Bandura, 1986; Kanfer, 1977). However, as Kluwe and Friedrichsen (1985) suggest, self-regulation itself requires cognitive/attentional resources. To obtain the beneficial consequences of self-regulation there must be cognitive resources available for engaging in self-regulatory activity. When self-regulatory activities demand resources that can *only* be provided through a reduction in resources demanded by the task, operation of self-regulatory activities may exert a cognitive cost that impairs learning and performance. This situation (in which tasks demand almost full use of available cognitive resources) frequently occurs when persons first encounter a difficult or complex task.

By integrating self-regulation demands and cognitive resources, it is possible to consider self-regulation in the context of skill acquisition. This perspective suggests that the engagement of self-regulatory activities when the task is resource dependent (e.g., during the declarative phase of skill acquisition) will deprive the task of needed resources. Unless the benefits of self-regulation are stronger than the costs of resource diversion, performance (and subsequent learning) will suffer. Following the development of a declarative representation of the task (i.e., in the knowledge compilation or procedural phases of skill acquisition) however, the engagement of self-regulatory activities are expected to enhance performance. This benefit is expected to be due to the availability of cognitive resources (for self-regulatory activity) and the consequences of self-regulation that serve to increase resource allocation to on-task activity.

III. TOWARD A UNIFIED MODEL OF SKILL ACQUISITION

By mapping abilities and motivation to the performance-resource function, a learner's performance may be represented as a joint function of the learner's relative attentional capacity (i.e., cognitive ability), task demands (i.e., phase of skill acquisition), and the proportion of the learner's total capacity actually devoted to the task (i.e., motivation).

Figure 2 illustrates the integrated framework underlying the current research. As shown, the model represents a modification and elaboration of Kahneman's (1973) model of attentional capacity (Kahneman, 1973; Figure 1-2, p. 10). Attentional capacity is viewed as an interindividual differences attribute. Attentional resources are allocated across different activities; feedback loops are posited for adjustment of allocations, proportion of total capacity allocated, and for external influences at both the level of allocation of capacity and allocation policy. In contrast to Kahneman, however, our representation explicitly distinguishes among three types of possible activities: (a) off-task activities, (b) on-task activities, and (c) metacognitive/self-regulatory activities. A basic assumption underlying our model is that changes in the amount of capacity utilized and policies for allocation of attention are accomplished through motivational processes.

The resource framework also provides a means of conceptualizing dynamic changes in performance as a function of abilities, motivation, and task characteristics. Over time, distal and proximal motivational processes influence the re-allocation and/or mobilization of additional portions of capacity to various activities. When task resource demands are high, the individual may allocate more available attention to the task, or adjust the proportion of capacity engaged. Conversely, when task demands are reduced, the individual may attend to off-task activities and/or may reduce the proportion of capacity engaged.

In this model, self-regulation is an essential mechanism for bringing about changes in allocation policy toward a task or total proportion of resource capacity actually engaged. Without activation of self-regulatory processes, for example, performance feedback would have little influence on learning and the individual would be expected to continue to devote the same amount of resources originally committed to a task from distal decision processes.

Individual differences in ability level/resource capacity will determine the total amount of resources that can be devoted to any set of activities. Consistent with **Figure 2**, low-ability learners must devote a greater portion of their capacity than higher-ability learners in order to achieve similar levels of task performance.

However, **Figure 2** is a static representation of ability and motivational processes. Changes in the performance-resource function that occur during skill acquisition are not directly represented in the figure but are addressed in the integrated framework. As noted previously, a potential drawback to activation of self-regulatory processes is that such processes may draw away resources needed to develop a declarative representation of the task. In this initial, resource dependent phase of learning, self-regulatory activity itself represents a "cognitive cost" and the products of self-regulation cannot be readily realized.

Changes in the true performance-resource function are posited to be detected by self-regulatory processes (i.e., self-monitoring of performance feedback and effort allocations). As the task becomes less resource-dependent (over practice), learners discover that fewer resources need to be devoted to the task to maintain performance. As such, resources might be diverted to other activities, including additional self-regulatory processing. Alternatively, an advanced learner may choose to reduce the proportion of attentional capacity currently engaged. To the degree that self-regulatory activities in tasks approaching resource-insensitivity not only enables motivational processing without costs but further increases, directs, and sustains on-task attentional effort, external influences that prompt self-regulation as task resource demands decrease may enhance performance. Taking into consideration individual differences in ability, the detrimental and beneficial effects of self-regulatory activity in the declarative and later phases of skill acquisition, respectively, are expected to be greater for lower-ability learners than high-ability learners.

IV. EMPIRICAL RESEARCH BACKGROUND

Empirical support for the integrated model was provided in three previous experiments by Kanfer and Ackerman (1989(a), 1989(b)). The results of these experiments provided initial support for the model and served as the foundation for the current program of research. The Air Traffic Control (ATC) task paradigm used in the completed studies is described in detail in the attached **APPENDIX**. The results of these experiments are briefly reviewed below. (Participants for these studies were 1,010 U.S. Air Force trainees at Lackland Air Force Base, Texas.)

Experiment 1. In this experiment, the basic learning and ability/performance parameters of the ATC task were evaluated in conjunction with a goal-setting intervention early in practice. All learners received task instructions and performed 10, 10-minute ATC task trials. Learners in the Early Goal condition were assigned a performance score goal on ATC task Trials 2 - 4. Learners in the No Goal, control condition did not receive specific performance goal assignments.

Consistent with our integrated model, the influence of general ability on performance attenuated as attentional demands of the task declined with practice. This pattern was further reflected by greater performance improvement of lower-ability learners with practice, compared to higher-ability learners (i.e., a *convergence* of higher and lower-ability learners).

The pattern of ability-performance correlations in the Early Goal condition provides some evidence of a demand on cognitive resources associated with the goal assignment. However, goal assignments made during the initial stage of skill acquisition exerted no effects on mean performance. Low levels of self-reported confidence in goal attainment and the relatively low-level of performance-checking among learners in the Early Goal condition suggested that the goal manipulation stimulated only minimal self-regulatory activity among Early Goal learners.

Experiment 2. The purpose of this experiment was to examine the facilitative effects of a goal setting manipulation in the context of skill acquisition. In this experiment, learners in a Late Goal condition were assigned a performance goal during Trials 5 - 7. The imposition of a goal following the development of a declarative representation of the task was *not* expected to shift critical resources away from task performance. Furthermore, since we expected spare resources to be available, the increased task effort by-product of self-regulation was predicted to be reallocated back into on-task activities.

Results obtained in this experiment demonstrate that the performance goal assignment provided during the intermediate stage of skill acquisition enhanced task performance. The gradual decline of general intellectual ability - performance correlations across trials provided evidence indicating that activation of self-regulatory activity did not drain resources from task performance but in fact may have redirected attentional effort toward the task.

Learners in the Late Goal condition appeared to engage in more self-regulatory activity than Early Goal condition learners (in Experiment 1). Two possible explanations for this finding were posited. First, the difference in self-regulatory activity might be due to a cognitive contingency mechanism that might control the operation of self-regulatory activities depending upon the attentional demands of the task. Such a mechanism might be associated with yet unspecified learning abilities. Alternatively, differential self-observation of performance made by learners in the Early and Late Goal conditions might have affected their willingness to engage in self-regulatory activity. A final experiment in this series was conducted to provide a test of these explanations and to investigate the joint effects of ability differences, self-regulatory activities and attentional/information-processing demands of the task.

Experiment 3. In this experiment we altered the information-processing demands of the task with a set of two different part-task training procedures, denoted "declarative" and "procedural." The declarative knowledge part-task training procedure was implemented in order to reduce the attentional demands of the full ATC task. This rule-learning training procedure was designed so that learners begin the full ATC task at a point close to where the resource demands were diminished. The procedural knowledge part-task training procedure was also structured to facilitate task performance, but to do so without reducing cognitive/declarative resource demands of the full task. Procedural knowledge training only focused on the development of the motor sequence skills that facilitate performance in the full ATC task. As such, there is positive transfer-of-training to the full task, but the cognitive/declarative attentional resource demands of the task have not been markedly reduced. Thus, learners engaged in procedural part-task training were expected to begun the full-task at a point where resource demands for performance remained high. Since both types of part-task training were expected to facilitate performance in the full ATC task, learners in both training conditions were expected to demonstrate similar levels of performance confidence and willingness to engage in self-regulatory activity.

Results obtained demonstrate that full ATC task Trial 1 performance in both Declarative and Procedural No Goal part-task training conditions was superior to Trial 1 performance in the No Goal condition run in Experiment 1. Part-task training raised performance an average of 42% above novice performance in the No Goal (no part-task training) control condition. Both ability level and type of part-task training influenced recall measures of declarative knowledge following task performance. Learners in the Declarative part-task training condition and higher-ability learners remembered more rules than lower-ability learners and learners in the Procedural training condition, respectively.

The performance results obtained support our integrated model. In the procedural training condition (see **Figure 3**) goal assignments had a negative influence on performance, with a larger dysfunctional effect obtained for lower-ability learners than higher-ability learners. In the Declarative training condition, goal assignments had a positive influence on performance, with a larger beneficial effect for lower-ability learners than higher-ability learners (see **Figure 3**).

V. CURRENT RESEARCH -- THEORETICAL ISSUES

The three experiments previously conducted provided initial support for the integrated resource model. In addition, the findings obtained raise several critical issues to be addressed in our proposed program of research. The relevance of findings to date as they pertain to these issues is discussed in turn.

Resource demands and motivational processes. The imposition of a specific performance goal assignment during the intermediate stage of skill acquisition benefitted the lower-ability learners more than the higher-ability learners. Although higher-ability learners are likely to be at a more resource insensitive area of the performance-resource function, the self-regulatory strategies employed by these learners may have failed to redirect now available attentional resources toward task components. During intermediate stages of skill acquisition, individuals have sufficient attentional resources for evaluative concerns. The byproduct of such concerns may be allocation of a greater proportion of resources directed toward task components. *Therefore, in this situation, we increased the learning of lower-ability learners.*

It is also important to note, however, that the provision of a performance goal assignment during the declarative stage of skill acquisition decremented performance among both low and higher-ability learners. Consistent with our model, the activation of self-regulatory activities via goal assignments diverted critical attentional resources away from task components. However, among higher-ability learners, the detrimental influence of the goal assignment on performance diminished with practice; among lower-ability learners, the detrimental effects of the goal assignment emerged with practice. This finding suggests that the extent to which motivational interventions, such as goal assignments, compete with attentional demands imposed by the task depends on the character of the self-regulatory strategies activated.

Examination of behavioral and self-report measures of attentional activity in the declarative - goal conditions indicated that lower-ability learners allocated relatively more attention to affective and evaluative activities than higher-ability learners (e.g., more performance/goal checking, more frequent reported attention to how they were doing compared to others). From a resource perspective, these findings strongly suggest that the goal assignment may have triggered dysfunctional self-regulatory strategies among lower-ability learners. Self-regulatory strategies that direct needed cognitive resources toward peripheral task components (such as affect) would further reduce the availability of attentional resources toward task components and retard skill acquisition. In contrast, higher-ability learners, who appeared to recover quickly from imposition of the goal assignment during the declarative phase of skill acquisition, demonstrated less performance/goal checking and reported fewer evaluative and affective thoughts than lower-ability learners. Among these learners, the performance goal assignment did not appear to trigger use of dysfunctional self-regulatory strategies.

The research in metacognition and goal-setting (e.g., Dweck & Leggett, 1988; Nicholls, 1984) has direct relevance for clarifying this pattern of results. Recent theorizing in metacognition suggests that specific features of the goal assignment may trigger different self-regulatory strategies. For example, goal assignments may be classified as imposing learning or performance orientations. Learning goals emphasize personal mastery and the use of self-regulatory strategies that direct attention toward task components. Performance goals stress demonstration of one's ability relative to a standard and are posited to trigger the use of self-regulatory strategies that direct attention toward evaluative concerns. In our earlier experiments, the specific goal assignment we provided was most similar to this class of performance goals. Although such goals do trigger self-monitoring (and thus impose cognitive costs during the early stage of learning), the byproducts of self-regulatory strategies associated with these goals can create additional attentional demands that further impair skill acquisition during the initial stage of learning. As resources are made available during intermediate stages of skill acquisition, the byproducts of performance-oriented self-regulatory strategies may lead to mobilization and/or redirection of now available cognitive resources.

Theorizing about the metacognitive influence of the goal assignment may be integrated with our resource model by distinguishing attentional demands associated with self-regulatory activities per se (e.g., self-monitoring) from attentional demands and benefits associated with specific self-regulatory strategies that coordinate effort allocation.

Consistent with our model, the costs and benefits of self-regulatory strategies depend upon individual differences in attentional capacity and upon task demands. Provision of mastery-oriented goal assignments during the declarative stage of skill acquisition is expected to reduce the cognitive cost of self-regulatory processing, particularly among lower-ability learners. Reduction of cognitive costs associated with use of self-regulatory strategies that further divert attentional resources should attenuate the size of the general intellectual ability-performance correlation at the outset of task performance compared to a performance-oriented goal condition. Furthermore, the provision of performance-oriented goal assignments during intermediate stages of skill acquisition is predicted to enhance performance through its effects on resource allocation to the task, especially for higher-ability learners. In comparison to a no-goal control condition, we expect this manipulation to disrupt the typical decline in the ability-performance correlation that occurs with practice.

Investigation of the specific features of motivational interventions associated with changes in the ability-performance relation provides a framework for more precise assessment of how self-regulatory processes influence skill acquisition. In addition, this research permits assessment of potential individual differences in learning abilities that may originate in the motivational/metacognitive system.

Individual differences in ability and transfer of training. A continuing problem in the skill acquisition literature concerns identification of the sources of individual differences in transfer-of-training. Results obtained in Experiment 3 (above) provide evidence that may be used to provide a theoretical analysis of transfer-of-training effects on the basis of our resource model.

Figure 4 displays the relationship between general cognitive ability level and full ATC task performance at Trial 1 following procedural part-task training. Three features of this figure are noteworthy. First, as shown in **Figure 4**, procedural part-task training resulted in a substantially higher ability-performance correlation than obtained in the no part-task training control condition, which means that higher-ability learners show greater transfer-of-training, consistent with earlier theory by Sullivan (1964). Second, the imposition of a goal assignment following the procedural part-task training attenuated the ability-performance correlation. Specifically, it appears that the attentional resource diversion demanded under the goal conditions had its greatest negative impact on just those higher-ability learners who would otherwise have been able to benefit from the transfer situation. Similarly, the detrimental effects of the goal on transfer in the declarative condition were mainly concentrated with the higher-ability learners. The effect was diminished, though, consistent with the attentional resource diversion hypothesis underlying the manipulation. That is, given that attentional (declarative) resource demands were reduced by the declarative training, but not by the procedural training, the impact on higher-ability learners should be diminished in the declarative-goal condition. These results are quite interesting, and merit further study, as described in the proposed experiments below.

VI. OVERVIEW OF CURRENT EMPIRICAL INVESTIGATION

Experiment 1. Emotion Control, Motivation Control, and Transfer-of-Training. The first series of experimental conditions extended the results from our previous investigation on the ability and self-regulatory effects of goal setting on individual differences in skill acquisition. Specifically, this experiment focused on three aspects of the transfer-of-training environment that affect skill development in full-task situations. These three aspects are: (a) Cognitive ability and individual differences in transfer-of-training, (b) Emotion Control (self-regulation) during skill acquisition and (c) Motivation Control during skill acquisition.

The first aspect of this investigation is to further explore the relationship between general cognitive ability, type of transfer, and attentional demands. Our previous results (Kanfer & Ackerman, 1989(a), Experiment 3, described earlier) indicated a stronger relationship between general ability and task performance at transfer (after procedural training) than was found in a control condition (from Experiment 1). However, when attention was diverted via the goal manipulation, the sizable advantage of higher-ability learners was seriously impaired, while lower-ability learners were less affected. The previous experimental conditions revealed this striking relationship without providing an opportunity to directly test our model's predictions of the causes of the phenomenon. By building on Kuhl's (1985) distinctions among self-regulatory strategies, we separate motivation control (i.e., amount of effort allocated to the task) from emotion control (which involves self-regulation of affective processing -- e.g., evaluation apprehension). This distinction allows us to delineate the affected mechanisms underlying the decline in higher-ability learner performance (in the goal condition), and to gain an understanding of the basis for the initial transfer-of-training advantage of higher-ability learners.

The second and third aspects of this series of experimental conditions are to explicitly separate the effects of emotion control and motivation control self-regulation strategies on skill acquisition. According to our conceptualization of attention, ability, and self-regulatory processing, these two metacognitive mechanisms (emotion control and motivation control) operate in a differential manner when attentional resources are scarce (e.g., during a novel task), but that can be coordinated in a mutually facilitative fashion when spare attentional resources are available for self-regulation. In our previous experiments, we found that lower-ability learners were severely hindered during skill acquisition when attentional resources were scarce and goals required emotion control. The extension of these results is that to increase the effectiveness of training (especially for lower-ability learners, emotion control strategies are necessary early in skill acquisition, but must be augmented by motivation control strategies when the attentional demands of the task are diminished (as the skill is acquired). This combination of interventions is expected to prevent the early asymptotic performance of lower-ability learners we found under our procedural training, goal conditions.

Given the above basis, the experimental sequence planned for the first series of studies includes five conditions: (1) Control condition - procedural pretraining, (2) Point

Goal condition (no motivation or emotion control intervention), (3) Emotion Control condition, (4) Motivation Control condition; and (5) Combined Emotion Control/Motivation Control condition. The results from this sequence of experimental conditions allow us to compare the independent and combined effects of Motivation Control and Emotion Control on skill acquisition, in addition to the effects of these processes on the ability-performance relations, especially via the evaluation of transfer-of-training effects. The *significance* of these comparisons is that they provide substantial knowledge about the mechanisms that underlie both the engagement and operation of motivational processes, as well as an understanding of the interactions among knowledge acquisition and extension (transfer), cognitive-intellectual ability, and attentional resource mechanisms. Such information may ultimately lead to programs of training that remediate problems of some lower-ability learners, as well as programs that may enhance higher-ability learner skill acquisition.

Experiment 2. Self-Regulation, Metacognitive Knowledge Training and Skill Transfer. One salient aspect of self-regulatory processes and metacognitive knowledge is the possibility that these constructs represent aspects that are trainable. That is, given that consistency underlies the productive use of self-regulatory processes for skill acquisition and performance maintenance, we believed that it possible to facilitate performance via direct training of self-regulatory "skills." In contrast to other researchers (e.g., Brown, 1987) who have focused on strategies for cognitive processing, our focus has been on the interplay of two other components of the self-regulation -- metacognition complex. Specifically, these two components are "motivation control" and "emotion control" (discussed briefly above). Experiment 1 was devoted to demonstration of the independent and interactive effects of motivation control and emotion control during skill acquisition. In contrast, Experiment 2 was devoted to training the consistent components of motivation control and emotion control, within a newly created part-task training paradigm. Our evaluation of these manipulations is derived from full-task performance, which required a generalization of these two control mechanisms for optimal skill acquisition. (The new part-task training procedures are called "minitrials," and they required subjects to formulate both declarative and procedural representations of the ATC task requirements, but in a limited, structured environment. This minitrial procedure is discussed in detail below, under the methods for Experiment 2.)

The second experiment involved two different experimental conditions, each of which was embedded in a Minitrial part-task training -- full ATC task transfer. These two conditions are as follows: (1) Part-task training with integrative self-regulatory training in motivation control (only); (2) Part-task training with integrative self-regulatory training in emotion control (only). A control condition (i.e., the "no goal, procedural part task training") will be used to make comparisons to baseline conditions. Our results were expected to demonstrate the independent and interactive importance of these two self-regulatory strategies on later, generalized (transfer) skill acquisition, and, a set of aptitude-treatment interactions. Specifically, we expected that the self-regulation training will benefit all learners, but the lower-ability learners are expected to benefit most. In addition, the beneficial effects for the lower-ability learners were expected to occur for the emotion control condition early in full-task engagement. In the motivation control condition, the facilitative effects on skill acquisition were posited to come earlier for the higher-ability learners, and later in practice for the lower-ability learners.

The significance of these various results was expected to be for specification of the "skill" nature of self-regulation, and for further exploration of the differences in learning/conation interactions with ability level. If, as expected, these self-regulatory strategies could be trained, it may ultimately be possible to gain more precise assessment of learning abilities, independent of self-regulatory activity during learning, and thus, better prediction for asymptotic skilled performance in complex training situations. Finally, this series of experimental conditions facilitates a comparison between the cognitive and conative determinants of the locus of higher-ability -- lower-ability learner differences in skill acquisition rates.

VII. EXPERIMENT 1.

Apparatus

Instructions, stimulus presentation, and response collection were implemented with Zenith Z-248 microcomputers running MS-DOS, with standard keyboard (numeric keyboard on the right side of the keyboard) and cathode-ray-tube monitors with short-persistence phosphor. A schematic keyboard diagram and a key function diagram, indicating which keys were to be used (and the function of those keys) were placed on the right of the computer keyboard. A template, indicating rules associated with computer keys #1 - 6 was also taped above the top number row of the keyboard, to assist subjects in selecting the correct key for calling-up specific ATC rule displays.

Each subject sat at an individual microcomputer workstation, within a carrel. The carrels provided visual restriction to the subject's own display. The carrels also provided moderate sound restriction, which was supplemented with a white-noise type effect from computer cooling fan and central ventilation systems. The result was a generally undisturbed environment for the individual subjects. At the conclusion of the experiment, data were off-loaded from the Zenith microcomputers to a mainframe computer for storage and data reduction. Data collected from each subject included all self-report and performance measures as well as all keystroke responses made during each performance trial.

Subjects

Participants in Experiment 1 were U.S. Air Force enlisted personnel undergoing basic training at Lackland Air Force Base, Texas. Subjects were tested in intact "flights," approximately 25-39 recruits at a time. Record keeping difficulties precluded obtaining exact age information for the subjects. However, most subjects were between 18 and 22 years old at the time of testing. (Prior to data analysis, data from some subjects were discarded, some for a lack of ability test records, and others for failure to follow task instructions. Finally, because a few subjects had incomplete data (e.g., computer failure, sickness), the degrees of freedom differ by as much as 2 or 3 *df* on some analyses). The final sample size was N = 588.

Procedure

Subjects began the experiment at individual workstation carrels. Prior to instruction on the ATC task, all subjects completed a series self-report measures designed to assess individual differences in specific motivation-related dispositions. Following administration of dispositional measures, all subjects received general instructions for performing the Air Traffic Controller task.

Choice/simple reaction time testing. A three-segment test of perceptual speed ability was administered on the computer. Subjects were given a brief set of instructions preceding each segment. The segments and procedure were as follows:

Four-Choice RT. Stimuli were digits 1,2,4,5. Responses were made using the same number keys on the computer numeric keypad.

Two-Choice RT. Stimuli were digits 1,2. Responses were made using the same number keys on the computer numeric keypad.

Simple RT. Stimulus was the digit 1. Responses were made using the same number key on the computer numeric keypad.

For the choice RT tests, each trial consisted of a focus dot for 800 msec, the stimulus presentation, and feedback (RT, Average RT, and cumulative accuracy over a block of trials). One block = 25 trials. (Performance was measured as the mean RT in msec for correct responses.) The Choice-RT tasks had stimulus *uncertainty* and temporal *certainty*. For the Simple RT task, a random duration focus dot was used to introduce time uncertainty, given the lack of stimulus uncertainty. Thus, the Simple RT task had stimulus *certainty* and temporal *uncertainty*. The focus dot was displayed for durations with a boundary of 800 to 1200 msec. Each of the three tests was administered in a standard format with two, 25-trial blocks.

Air Traffic Controller Task (general instructions). The ATC task instructions were both narrative and interactive. For the most part, subjects read about the task components, commands, rules and procedures. Interactive instruction is provided for such keyboard response procedures as: (a) accepting planes from the queue, (b) moving planes in the hold pattern, (c) landing planes onto a runway, and (d) initiating a rule call-up. Instructions were subject-paced, but most subjects completed the instructions in approximately 20 minutes.

Procedural part-task training. After the initial task instructions, subjects received practice in *learning the keyboard response procedures* of the task. Subjects were shown a series of dynamic task scenarios (presented in real time) and subjects were instructed to complete the key sequence that was displayed on the screen. An example of a trial task scenario is shown in the **Figure 5**.

Each trial/key sequence scenario represented logical moves (or series of moves) that would be followed by a skilled ATC task performer. As illustrated in the figure, a subject could be shown a scenario with a plane in Position "2e" of the hold pattern. The instructions tell the subject to perform the specific key sequence that would select the plane, move it from Level 2 to Level 1, and then from Level 1 to an appropriate runway. Subjects were instructed to press the keys rapidly, but also to note the results of the key-presses which were displayed on the screen as the keys were pressed. If an incorrect key was pressed, the trial ended, and the subject was shown and "Error" message. Otherwise, after completion of each correct key sequence, subjects were shown a "Correct" message. In addition, accuracy information was presented at the end of each of 30 trials. Subjects received 5 blocks of trials. The length and complexity of key sequences increased within and across trial blocks.

Full ATC Task Transfer: Overview. Following the procedural part-task training, five transfer conditions were created (between-subjects manipulation): (a) Control, (b) Goal, (c) Emotion Control, (d) Motivation Control, and (e) Emotion/Motivation Control Combined. Subjects in each condition performed nine, 10-minute full ATC task trials and completed short computerized self-report measures immediately following Trials 3, 6, and 9. Subjects in the all conditions except the Control condition received specific and difficult goal performance goal assignments immediately prior to each of the first six task trials.

Prior to Trial 7, subjects in all conditions were provided with non-specific "do your best" instructions for performance on each of the last three task trials. After completion of task Trial 9, all subjects completed a computerized self-report questionnaire assessing the frequency of on- and off-task thoughts during ATC performance. After the final questionnaire, all subjects were administered a "Rules/Knowledge Test." In this test, subjects were required to write out (with pencil and paper) the six rules governing performance on the ATC task in as much detail as possible. When subjects returned the forms they were debriefed and excused.

Control (No Goal condition). Subjects in this condition were instructed to "do your best" prior to each of the nine ATC task trials. These subjects were told: *Your objective in the next trial is to get the best performance score you can."*

Goal condition. The procedure described for the Control group was repeated with the Goal group, with the following exceptions. Task - specific motivation was manipulated by assignment of a specific and difficult performance goal for each of the first six task trials. Subjects in the Goal condition received their first goal assignment prior to the first full-task trial. Subjects were assigned a cumulative performance goal (for each trial) of 1700, 2500, 2700, 2900, 3000, and 3100 points for task Trials 1 through 6, respectively. These point goals were selected on the basis of results obtained in pilot experiments (no goal) with the ATC task. Pilot data indicated that 1700 points represented a difficult performance goal (approximately 90*th* percentile) for Trial 1. Point goal scores for subsequent trials represent increases in accordance with the criterion that the goal remained difficult (corresponding to approximately a 90*th* percentile level).

Prior to performance of each task trial, subjects in the Goal condition were informed of their performance goal assignment for the upcoming trial. For example, prior to task Trial 1, Goal condition subjects were told:

> *For the first task trial, you have been assigned a specific performance goal.*
>
> *Your assignment is to reach a PERFORMANCE SCORE OF 1700 POINTS by the end of the trial.*

In addition to the performance goal assignment, subjects in the Goal condition were given the opportunity to periodically check their goal progress during the six assigned goal trials. Subjects were told:

> *You can check on how well you are doing by "calling up" more performance information. Several times during the trial, a special signal, (* * * * <F10> * * * *) will appear at the top right of your screen.*
>
> *When this signal appears, you may press the F10 key to get more information about how you are doing, relative to your performance goal assignment.*

The "F10" signal was displayed for 10 seconds for each minute of each trial (beginning 1:00 min into the trial). Subjects who pressed the F10 key during the signal received a message at the bottom right of their screen indicating the percent of the goal they would obtain. This goal/performance feedback was calculated by extrapolating from the subject's current performance, divided by the assigned goal point total. An example of the message displayed is: "*Based on your current performance you will attain 80% of your goal.*"

Emotion Control condition. The same procedure described for the Goal group was repeated with subjects in the Emotion Control condition, with the following exceptions. Following the performance goal assignment, subjects were instructed to use an emotion control strategy while performing the task. Instructions on the use of this strategy were provided prior to each of the first six trials. Immediately following emotion control instructions, subjects were reminded of their performance goal assignment.

Emotion Control strategy instructions directed subjects to control their emotions during ATC task performance. In particular, subjects were instructed to increase the frequency of positive thoughts and to reduce the frequency of negative emotions, such as worry or upset following errors. In accord with the need to implement a strong manipulation early in full task performance, elaboration of the emotion control strategy instructions was greatest prior to the first trial and was gradually reduced in subsequent task trials.

Motivation Control Condition. The procedure for subjects in this condition was identical to that used for subjects in the Emotion Control condition, with two exceptions. In this condition, subjects received motivation control strategy instructions rather than emotion control instructions. Motivation Control strategy instructions directed subjects to control and further increase the amount of effort they devoted to the task at all times during the trial. Given the requirement of a strong manipulation during later task trials, elaboration of the motivation control strategy instructions was weakest prior to the first trial and was gradually increased over subsequent task trials.

Emotion/Motivation Control Combined Condition. Procedures for this condition were identical to those used in the previous three conditions with the exception of strategy instructions. In this condition, emotion control and motivation control strategy instructions were combined to provide both types of strategy information. Instructions started with emphasis on emotional control during early task trials and gradually shifted to emphasis on motivation control during the later task trials. For example, instructions prior to the first task trial directed subjects to give the task their full effort by controlling their emotions during ATC task performance. Subjects were told to control their emotions by increasing the frequency of positive thoughts and reducing the frequency of negative emotions. Prior to the final task trial, the instructions emphasized improving performance by further increasing the amount of effort they devoted to the task at all times during the task trials.

Dependent Measures

Dispositional measures. Measures of individual differences in self-regulatory dispositions were obtained from self-report questions administered at the onset of the session. Items from these questionnaires were used to derive three composite measures of action control orientation (Performance, Failure, and Decision), two composite measures of personality (Control and Stress), and one composite measure of cognitive failure frequency

Action Control. All subjects completed a modified English version of the short-form Action Control Questionnaire (HAKEMP 88 ACQ; Kuhl, 1985). The ACQ is designed to assess individual differences in attentional focus in three dimensions of problem situations. Individuals high in action control are self-described as directing attention toward behaviors necessary for goal accomplishment. In contrast, persons low in action control, that is, high in state orientation, are characterized as prone to directing attention toward emotional aspects of the problem (see Kuhl, 1981, 1985). Subjects completed 48 forced-choice items. These items form three 16-item scales; (a) Performance, (b) Failure, and (c) Decision-Making. Items on the Performance scale pertain to action control tendency with respect to executing intentions (e.g., "When I am facing a big project that has to be done"). Failure scale scores reflect individual differences in action control following failure experiences (e.g., "When I am told that my work has been unsatisfactory"). Decision-making scale scores are designed to indicate strength of action control during task performance (i.e., tendency to remain focused on the task). Scores on each scale range from 16 (state orientation) to 32 (action orientation).

Personality. Following completion of the ACQ, subjects received instructions for completing two subscales of the Multidimensional Personality Questionnaire (MPQ; Tellegen, 1982). The MPQ is a factor-analytically developed self-report instrument designed to assess eleven primary personality dimensions (see Tellegen, 1985). Fifty self-report items comprising the Control and Stress subscales of the MPQ were administered. For each item, subjects were instructed to indicate whether the statement provided was self-descriptive, using a True/False format. Persons with high scores on the Control scale are characterized as cautious and planful. Persons with high scores on the Stress scale are characterized as prone to worry, easily upset, and anxious. Scores on each scale range from 25 to 50.

Cognitive Failures. Subjects then received instructions for completing a modified form of the Cognitive Failures Questionnaire (CFQ; Broadbent, Cooper, FitzGerald, & Parkes, 1982). The CFQ is a 25-item self-report measure designed to assess common cognitive failures in perception, memory and motor functions related to stress (e.g., "Do you fail to notice signposts on the road?" "Do you drop things?"). Subjects reported the frequency of occurrence using a four-point scale ranging from never (1) to very often (4). Three items from the original CFQ measure were deleted on the basis of evidence indicating poor validity and reliability.

Self-reports of self-regulatory/metacognitive activities - Goal related measures. Self-report questionnaire items were used to assess self-regulation components. Items were selected on the basis of previous empirical evidence of inter-item reliability and construct validity (e.g., see Kanfer & Ackerman, 1989(a)). With the exception of the expected performance score item, 8-point Likert scale formats were used for all responses. To assess expected performance score, subjects were instructed to report the actual performance score they expected to attain on the upcoming task trial.

To examine the impact of the manipulations on self-regulatory processing, five items were administered immediately following the first goal assignment and prior to task Trial 1, and again prior to task Trial 3. Three items assessing goal commitment (e.g., "How committed are you to working as hard as possible to reach the assigned performance goal?"), were summed to form a composite goal commitment scale score. A self-confidence for goal attainment composite score was obtained by summing two items (e.g., "How certain are you that you have the ability to achieve the assigned performance goal?"). Reliabilities for the goal commitment and self-confidence composite scales ranged from r_{xx} = .74 to .86.

Goal attentiveness, performance monitoring, and performance satisfaction were examined using six items administered immediately following completion of task Trial 3 and again following task Trial 6. Four items were summed to provide a composite goal attentiveness score (e.g., "How often did you think about your assigned goal during the last task trial?") and two items were summed to provide a composite score of performance monitoring (e.g., "How often did you check your performance score during the last trial?"). Performance satisfaction was assessed with a single item, "How satisfied are you with the performance score you obtained on the last trial?" Reliabilities for the composite performance monitoring scales were r_{xx} = .47 and .49; reliabilities for the goal attentiveness scale were r_{xx} = .77 and .81.

Subjects in all conditions completed a final self-report questionnaire following Trial 9. This questionnaire contained items designed to assess the frequency of various types of thoughts during the final set of trials (Trials 7-9), and state measures of positive and negative affect. The occurrence of various types of thoughts during the final three trials of ATC performance was assessed by using a modification of Sarason's Cognitive Interference Questionnaire (CIQ; Sarason, 1978; for a description of the CIQ, see Sarason, Sarason, Keefe, Hayes, & Shearin, 1986). The CIQ is designed to assess the frequency of intruding thoughts during task performance and requires subjects to indicate, using a 5-point Likert rating scale (1 = *never*; 5 = *very often*), how frequently the thought described in each statement occurred to the subject while performing a just completed task. The CIQ includes 22 items pertaining to thoughts about the task (e.g., "I thought about how poorly I was doing"), and off-task thoughts (e.g., "I thought about personal worries").

In our modified version, items were written to include thoughts about various aspects of the task (e.g., During the last three trials, I focused my total attention on making fewer errors"). A subset of adapted CIQ items and new items (e.g., assessing specific self-motivation thoughts and positive self-reactions) were administered using an 8-point Likert rating scale (1 = *never*; 8 = *constantly*). In particular, seven items related to attention to task components (e.g., "I focused my total attention on learning a specific rule"), two items related to negative self-reactions (e.g., "I got upset when I made a mistake"), four items related to positive self-reactions (e.g., "I thought about how well I was doing"), four items related to negative affect (e.g., "I thought about how dissatisfied I was with my performance"), two items related to off-task thoughts (e.g.,"I let my mind wander while doing the task"), three items related to self-motivation (e.g., "I pushed myself to do better on each trial"), and four items related to performance evaluation thoughts (e.g., "I thought about how I was doing compared with others."). Internal consistency reliability of composite scales ranged from r_{xx} = .64 to .86. The low reliabilities obtained for some of the self-report composite scales (e.g., negative self-reactions) are only problematic to the degree that the null hypothesis is not rejected. Corrections for reliability would only serve to accentuate the size of significant effects found in the data.

To investigate the impact of the manipulations on positive and negative mood states, subjects also completed the Positive and Negative Affect Scale (PANAS; Watson, Clark, & Tellegen, 1988). The PANAS is a 20-item measure that requires subjects to respond to a series of mood adjectives (e.g., "proud," "nervous") using a 5-point Likert scale (1 = *not at all*; 5 = *extremely*). Independent scores of positive and negative mood states are derived from summing 10 responses that relate to positive affectivity and 10 items associated with negative affectivity (for a review of the psychometric evidence, see Watson et al., 1986). Internal consistency reliability estimates of these scales ranged from r_{xx} = .87 to .90.

Ability measures. Estimates of *general* cognitive/intellectual ability were derived from a composite based on the ten test, Armed Services Vocational Aptitude Battery

(ASVAB). The ASVAB was completed by the subjects several months prior to the experiment and test scores were obtained from personnel records. The global estimate of cognitive ability (general intellectual ability) was obtained using a unit-weighted composite based on all 10 subscales of the ASVAB.[1] Subjects were then divided into higher-ability and lower-ability groups using a median split on the ability composite. This split was used as a two-level blocking factor in ANOVAs reported below.

Estimates of *Perceptual Speed* ability were derived from a composite based on the average performance of the Four-Choice, Two-Choice, and Simple Reaction Time tests administered at the beginning of the experimental session. Again, the estimate was obtained using a unit-weighted composite of all three tests.

Performance measures. Multiple measures of task performance were obtained at each trial, including number of planes landed (Landings), number of rule violations (Errors), number of keystrokes made (Keystrokes), cumulative performance score, mean reaction time to wind changes, and number of plane crashes. Three measures, landings, errors, and keystrokes, were used in all analyses of performance. Two of the measures (Landings and Errors) are displayed on the screen during the task and are combined to generate the cumulative performance score. These measures have the additional advantage over cumulative performance score of being ratio scale measures of performance. *The landings and errors measures were relatively independent, though negatively correlated (average correlation between the two variables for any given trial was* $\bar{r} = -.156, p < .01$*).* Other task-based measures were also obtained. Number of rule call-ups by all subjects, and number of performance/goal feedback call-ups by subjects in the Goal conditions were also recorded for each (goal-present) task trial.

Performance: Behavioral Measures -- Ability-performance results. As with previous investigations using the ATC task, one major set of hypotheses about task performance (Landings) pertained to initial ability - performance correlations, and changes in these correlations during skill acquisition. Given that the task was complex and novel (but one that involved consistent information processing demands), the expectation was that performance would be initially determined by general intellectual abilities. Furthermore, these correlations were expected to attenuate as practice continued. In contrast, correlations between perceptual speed measures were predicted to increase in association with performance, then decrease with later practice. (For a complete review of the theory of cognitive determinants of skill acquisition, see Ackerman, 1988). To assess ability-performance relations across task trials, ability composites were correlated with the performance variables, for each experimental condition. Correlations between the two key

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[1] The ASVAB is composed of the following sub-tests: General Science, Arithmetic Reasoning, Word Knowledge, Paragraph Comprehension, Numerical Operations, Code Speed, Auto Shop, Math Knowledge, Mechanical Comprehension, and Electronics Information.

abilities (a General intellectual ability factor and a Perceptual Speed ability factor) are presented in **Figures 6 - 9**.

Control vs. Goal Conditions. The first comparison regarding ability-performance correlations is that of the control (No Goal) and Goal conditions. As can be seen in **Figure 6**, aside from an initially equivalent high correlations between General ability and performance in both conditions(r = .453, .500, respectively) subsequent trials indicate that the Goal condition has substantially attenuated demands on the general ability. In addition, while the expected increase in association between Perceptual Speed and performance is found for the Control condition, the Goal condition shows an attenuated dependence on this ability as well. Overall, then, the motivational/self-regulatory effects of goal imposition, as with our previous investigations, shows a decreased dependence of task performance on individual differences in cognitive/intellectual abilities.

Given that the Goal condition is the appropriate "control" condition for the other three experimental conditions (in that they all have the same basic goal assignments, in addition to the other manipulations), the remaining contrasts are given in comparison to the goal condition (and sometimes, with respect to one another).

Emotion Control Condition. The prediction for the Emotion Control condition was that the manipulation would have the effect of diminishing the demands associated with the goal assignment (that is, reduce the resource load imposed by the goal). In that sense, the ability-performance correlations in this condition were expected to appear similar to the overall Control condition, that is, increased dependence on the General ability (as compared with the Goal condition), and increasing associations with Perceptual Speed ability. Indeed, as **Figure 7** shows, the expectations were largely borne out. In fact, the substantial rise in Perceptual Speed ability - performance correlations indicates that the Emotion Control condition actually facilitated development of the second (Associative) stage of skill acquisition, whereas the Goal condition did not.

Motivation Control Condition. As discussed earlier, the Motivation Control condition can best be thought of as a goal manipulation made more salient than the standard Goal condition. The increasing emphasis of the manipulation on keeping the subjects' efforts at their maximal level was predicted to result in increased demands on the general attentional capacity, as compared with the Goal condition. The respective ability-performance correlations are shown in **Figure 8**, and they are largely consistent with this prediction. While no salient differences can be found for the Perceptual Speed ability - performance correlations, the association between General ability and performance starts out at a slightly higher level than the goal condition (Trial 1), and the higher level is maintained throughout the nine task trials.

Emotion/Motivation Control Condition. Given the mixture of instructions conveyed to the subjects in this condition, it was difficult to spell out any specific temporal predictions regarding ability-performance relations. However, it was expected that initial performance in this condition would reflect the attenuation of demands on the attentional system early in task performance (when Emotion Control instructions were strongest). It was also expected that later performance would reflect increased demands for Perceptual Speed ability (when the second stage of skill acquisition is in progress, and when the early general ability demands associated with the first stage have diminished). In fact, as **Figure 9** indicates, the combined emotion/motivation control condition had General ability - performance effects similar to the Goal condition. The Perceptual Speed ability - performance results were less clear, with small increases in correlations taking place from Trials 3 - 6, and then variable correlations on the last three (non-goal) task trials. From these data, it was not clear what the general impact of this procedure was, additional data from the other performance measures were needed to fully understand the effect of the manipulation. These results are discussed in the sections that follow.

Results

Performance: Behavioral Measures -- raw task performance results. In addition to analysis of ability - performance correlations, the basic performance measures were examined separately. These results, across all five conditions, are presented below, by dependent variable. The main analyses, as with previous investigations, focused on the number of planes successfully landed, and the number of operational (rule) errors committed, within each of the nine 10-minute trials. In addition, based on developments to the program made subsequent to our last major investigation, it was possible to record the total number of keystrokes made by subjects within each trial. This measure is included in our current analyses in an effort to shed light on strategy and activity level issues.

Planes Landed. An omnibus repeated-measures ANOVA was performed for the Landings variable. The results of this analysis are presented in **Table 1**. As can be seen from this table, as well as visually illustrated in **Figure 10**, the major (and significant) influences on performance were Ability (the General ability composite), Trials (the practice variable), and an interaction between Ability and Trials. The plot of mean performance for higher and lower-ability subjects (based on a median split of the ability composite) is consistent with the general trends shown in the earlier correlational results by condition, that is, that General ability is an important determinant of task performance, but a determinant that attenuates in influence as task practice continued. The convergence of the higher and lower-ability groups at the later trials illustrates this basic datum.

In general, these results are consistent with earlier findings, though it was expected that further differences between the various goal and instructional conditions would be evidenced in the Landings variable. This did not appear to be the case. Instead, the various conditions seemed to have their respective impact on other indicators of performance and task strategy, as described below.

Errors. The error score analysis, while generally reflecting the same major effects found in the analysis of Landings (i.e., Ability, Trials, and Ability X Trials interaction), also showed an additional significant interaction effect, that of Ability X Treatment X Trials. This effect, which is shown graphically in **Figure 11**, shows several salient patterns across the various conditions. First, for lower-ability subjects, the Goal and Motivation Control conditions resulted in increased numbers of errors during task performance, which reflect the deleterious effects associated with increased demands on the subjects' attentional system. Conversely, the Emotion Control condition resulted in the least number of errors across task trials for the lower-ability subjects, a result that is consistent with the theoretical framework proposed in this project.

For the higher-ability subjects, the fewest errors across trials were obtained by subjects in the Motivation Control and Emotion Control conditions. While it was not expected that the Emotion Control condition would have as much of a benefit for the higher-ability subjects (as it did for lower-ability ones), the Motivation Control condition was expected to result in increased performance (fewer errors) for these subjects. The other facet of these data is the emergence of increased numbers of errors in the Emotion/Motivation control condition for the higher-ability subjects, a factor not reflected in the data from lower-ability subjects, and one that is not easily explained. It is not clear why a combination of two independently beneficial sets of instructions would lead to increased numbers of errors for the higher-ability group.

Keystrokes. Analysis of the total number of keystrokes (those associated with both successful and unsuccessful operations during the task) provides a new way of evaluating task strategy. On the one hand, increased keystrokes are associated with increased performance (especially early in skill acquisition, where the correlation between keystrokes and planes landed is $r = .584$ -- across all five conditions). On the other hand, later in task performance, the total number of keystrokes also partly reflects the inefficiency of strategies for task performance. That is, highly-skilled performers in the ATC task typically show more efficient use of the hold pattern, that in turn, reduces the total number of keystrokes needed for landing of each plane. While a more fine-grained analysis may be appropriate in future investigations, the overall number of keystrokes measure available for this experiment did reveal some interesting patterns and allow for several conjectures regarding the effects of the experimental manipulation on task strategies.

The analysis of Keystrokes for this experiment resulted in four major effects, as shown in **Table 1**, and illustrated in **Figure 12**. These effects were: Ability, Trials, Ability X Trials, and Treatment X Trials. Given the positive association between number of keystrokes and number of Landings, early in task performance, it was not surprising that higher-ability subjects used a greater number of keystrokes early in task performance. More interesting, though, is that the interaction of Ability X Trials indicated that the differences between higher and lower-ability subjects *increased* over task practice. That is, activity levels for these groups diverged, *even though ability differences in Landings and Errors decreased during the same period*. In some sense, this may be a function of diminishing returns for additional activity at skilled performance levels (e.g., many keystrokes are needed to move planes around, a procedure that can result in a marginal savings of fuel, but not in a difference in the number of planes landed).

The Treatment X Trials interaction, also shown in **Figure 12**, illustrates first of all, that activity levels were similar for two pairs of conditions (Control with Emotion Control, and Goal with Motivation Control). These pairings of conditions are generally consistent with our groupings of conditions based on increased/decreased load on cognitive resources. However, it was clear, but somewhat perplexing, that the combined Emotion/Motivation Control condition resulted in a substantial increase in Keystrokes as the task continued. Our tentative explanation for this effect is that it is a reflection of subject attempts to put forth more effort in the task (by increasing activity level) without the necessary concomitant increase in knowledge base that would have allowed for more efficient use of the hold pattern. That is, the decreased demands on the attentional system (from the early implementation of Emotion Control instructions) decreased the perceived need to "learn" the rules of the task, while the increased demands on the attentional system (from the late implementation of Motivation Control instructions) increased the perceived need to "engage" the task, without knowing how to efficiently do so. Additional investigation would be needed before this hypothesis can be sufficiently evaluated.

Self-report measures. A basic question in this experiment pertains to the differential influence of the emotion and motivation control strategy manipulations on self-regulatory activities in the context of a goal assignment. As designed, the Emotion Control and Emotion/Motivation Combined conditions provide subjects with essentially the same instructions during initial task trials. These instructions were hypothesized to weaken the disruptive influence of the performance goal assignment relative to the Goal and Motivation Control conditions. In the Motivation Control condition, instructions during the initial task trials were designed to provide instructions that reinforce the performance goal assignment. Thus, instructions in the Goal and Motivation Control conditions were expected to exert similar effects on self-regulatory processes. The similarity of these condition pairings was examined in a series of one-way ANOVAs comparing the Emotion Control and Emotion/Motivation Control Combined conditions and the Goal and Motivation Control conditions on self-regulation and attentional self-report measures. Results obtained in these analyses indicated *no* significant differences between the Emotion Control and Emotion/Motivation Control Combined conditions, or between the Goal and Motivation Control groups. In light of these findings, the Goal and Motivation Control groups were combined to form a "high demand" goal condition, and the Emotion Control and Emotion/Motivation Combined Control conditions were combined to form a "low demand" goal condition in all subsequent analyses of self-report measures.

Self-regulatory processes. A series of 2 X 2 ANOVAS were conducted on self-regulation composite scores to examine the joint impact of goal conditions and general cognitive ability. No significant differences were obtained on the goal commitment composite score taken prior to Trial 1 or Trial 4. Overall, subjects reported a high level of commitment for goal attainment throughout the experimental session (Trial 1 M = 4.30; Trial 4 M = 4.91). Findings obtained in analyses of self-report measures assessing self-regulatory activities covering task Trials 1 - 3 indicated significant main effects for goal condition on self-confidence for goal attainment ($F(1,471) = 5.37, p < .05$), goal attentiveness ($F(1,465) = 46.18, p < .001$), and performance monitoring ($F(1,465) = 5.71, p < .05$). Subjects in the high demand goal conditions reported lower levels of self-confidence (high demand $M = 6.05$; low demand $M = 5.38$), greater attentiveness to the goal ($M = 19.68$; low demand $M = 15.15$), and more frequent performance monitoring ($M = 5.95$; low demand $M = 5.23$) than subjects in the low demand goal conditions. A significant main effect for ability was also obtained for goal attentiveness ($F(1,468) = 9.78, p < .01$). Subjects in the lower-ability condition reported higher levels of attentiveness to the goal than subjects in the higher-ability condition (lower ability $M = 18.73$, higher ability $M = 16.19$).

Analyses of self-regulation measures covering Trials 4 - 6 indicate a similar, but not an identical pattern of results. Again, significant main effects for goal condition ($F(1,465) = 36.47, p < .001$) and ability ($F(1,465) = 5.41, p < .05$) were obtained for goal attentiveness. However, analyses of self-confidence for goal attainment and performance monitoring scores both showed significant main effects for ability (self-confidence, $F(1,471) = 4.46, p < .05$; performance monitoring, $F(1,465) = 4.15, p < .05$), but no significant main effects for goal condition. Prior to Trial 4, lower-ability subjects reported less self-confidence for goal attainment (lower ability $M = 7.70$; higher ability $M = 6.91$), and more frequent performance monitoring (lower ability $M = 6.39$; higher ability $M = 6.01$) than higher-ability subjects.

These results provide further support for the hypothesis that emotion control strategy manipulations attenuated the detrimental effects of the performance goal assignment on attentional resources. Instructions to implement an emotion control form of self-regulation led to significant reductions in the reported frequency of negative self-reactions and performance monitoring. These same components were previously found to be most closely associated with the diversion of attentional effort from the task (see Kanfer & Ackerman, 1989(a)).

Attentional measures. Analyses of self-report measures of cognitive activities during the final three task trials were consistent with results obtained on behavioral and self-regulation measures. On the composite measure of performance evaluation, a significant main effect for ability ($F(1,541) = 6.05, p < .05$) and a significant Ability X Condition interaction ($F(2,546) = 3.93, p < .05$) was obtained. Among lower-ability subjects, subjects in the low demand goal conditions reported fewer thoughts of performance evaluation compared with subjects in the high demand goal and no goal conditions. Among higher-ability subjects, however, subjects in the no goal and low demand goal conditions reported more frequent thoughts of performance evaluation than subjects in the high demand goal and control conditions. These findings are consistent with error score results suggesting that the emotion control manipulation most benefits lower-ability learners.

Significant main effects for goal condition were also obtained on measures of negative self-reactions ($F(2,541) = 3.99$, $p < .05$), positive self-reactions ($F(2,541) = 3.07$, $p < .05$), negative affect $F(2,541) = 8.88$, $p < .001$), and self-motivation ($F(2,541) = 3.02$, $p < .05$). Subjects in the Control and high demand goal condition reported more frequent distress associated with making mistakes, more frequent thoughts of dissatisfaction, and more frequent attempts to push themselves to work harder than subjects in the low demand goal condition. Significant main effects for ability were also obtained on negative self-reactions $F(1,541) = 9.50$, $p < .01$) and negative affect $F(1,541) = 31.49$, $p < .001$). Lower-ability learners reported more frequent distress following mistakes and more frequent thoughts of dissatisfaction than higher-ability subjects.

In summary, results obtained on self-report measures of self-regulatory activity indicate that the emotion control manipulations were effective in altering the pattern of self-regulatory activities engaged during ATC performance. The differential pattern of self-regulation demonstrated in the low and high demand goal conditions is consistent with the hypothesized process by which goal assignments reduce attentional effort toward the task. Self-regulatory activities and attentional processes among learners given the motivation control strategy instructions did not differ from learners only given the goal assignment. In these high demand goal conditions, learners demonstrated the typical pattern of resource-consumptive self-regulatory activities (e.g., monitoring of one's performance, negative self-reactions). In contrast, however, the provision of emotion control strategy instructions was associated with a less-resource-consumptive pattern of self-regulatory activity compared with the high demand goal conditions. Learners in conditions that instructed emotion control strategies thought less about achieving the goal, were more self-confident, reported less frequent negative self-reactions and negative affect, and reported less monitoring of their performance score.

Discussion

This experiment concerned the development of skills in a novel, complex, but consistent task. In the baseline (Control) condition, the General ability correlated highly with individual differences in ATC task performance, consistent with the theory and with previous results. Providing a specific, difficult goal (the Goal condition) increased attentional demands of the task, initially leading to higher ability - performance relations (given that higher-ability subjects were more able to respond to the "dual-task" like demands of the goal and the ATC task). With practice, though, lower-ability subjects were able to benefit from the reduced attentional demands of the ATC task, and redirect their effort to the goal, ultimately resulting in attenuated ability - performance correlations.

Embedding self-regulatory strategy instructions during full-task practice, led to changes in both ability-performance relations, and to changes in subjective responses to the learning situation. When training was given in Emotion Control, the deleterious "dual-task" like effects of the goal provision were *deflected*. As a consequence, subjects proceeded more quickly to the less-attentionally demanding phase of skill acquisition (evidenced by the increased correlations between Perceptual Speed and performance). In contrast, heightening the goal demands, by providing Motivational Control training, inflated the initial general-ability demands of the ATC task (by diverting attentional resources away from the ATC task proper, and to self-regulation of effort). In addition, the increased general-ability demands were maintained over the entire full-task trial sequence, as the strength of the intervention (instructions) was increased. Subjects responded appropriately to the intervention, by maintaining their general attentional effort, and by not allowing the task to proceed to an effort-insensitive state (this point was evidenced by the uniformly low correlations between Perceptual Speed ability and performance, even late in skill acquisition). High ability subjects responded to the Motivation Control manipulation by further reducing errors late in practice, as well as increasing their activity level (keystrokes).

Combining the two manipulations (Emotion and Motivation Control) was least beneficial to the higher-ability learners (relative to the other conditions), given that they were discouraged from worrying about their task performance early in skill acquisition, but were encouraged to put forth extra effort late in skill acquisition (presumably this is the opposite of how high-ability learners would generally approach the task). Taking into account the difference in practice functions for higher and lower-ability subjects, the lower-ability subjects were able to better benefit from the combined Emotion/Motivation Control manipulation, given that they were asked to increase their effort, while they were still at a resource-consumptive stage of skill acquisition. The increase in activity level found at the end of the practice sequence for the lower-ability subjects was not associated with the increase in error rates that was found for higher-ability subjects. From a performance perspective, the critical issue for combining self-regulatory skills with an embedded training procedure has to do with optimizing the timing of such instruction, given extant differences in a match between the dynamic attentional demands of the task, and the amount of attention available to the learner.

From a self-regulation perspective, "low demand" effects were found in both conditions that used emotion control strategy training (the Emotion Control condition, and the combined Emotion/Motivation Control condition). In *contrast*, "high demand" effects were found in the Goal (only) and the Motivation Control conditions. Subjects in the low-demand conditions reported higher self-confidence for goal attainment, less frequent monitor of the goals and performance, and fewer negative self-reactions to performance. That is, emotion control training reduced the negative impact of the goal on self-regulatory behaviors. The impact of these self-regulatory activities was a positive one on ATC task performance, particularly for lower-ability subjects. This finding was especially significant, given that previous and current results indicate that lower-ability subjects are more apt to otherwise engage in more frequent negative self-reactions during skill acquisition.

The absence of significant differences between the Goal and Motivation Control conditions on attentional measures taken after Trial 9 is noteworthy in light of the performance findings. The absence of significant differences between these groups on self-report measures of attention suggests that differences in performance were *not* due to differences in the resource demands imposed by self-regulation components (such as negative self-reactions). Rather, the demonstration of performance differences in keystroke activity and General ability - performance relations suggests that observed effects may be due to the (unmeasured) impact of the motivation control manipulation on metacognitive strategies governing how to perform the task. As such, the effect of the motivation control manipulation may have been to accelerate task activity at the same time that attentional resources devoted to the task had been reduced by the diversion of resources to self-regulatory activities. In this situation, one would anticipate a pattern of performance characterized by high, but inefficient levels of on-task activity. The observed pattern of performance for this group, relative to the Goal group, is consistent with this expectation.

VIII. EXPERIMENT 2

Apparatus

Apparatus used for Experiment 2 was the same as that used in Experiment 1.

Subjects

Participants in Experiment 2 were U.S. Air Force enlisted personnel undergoing basic training at Lackland Air Force Base, Texas. Subjects were tested in intact "flights," approximately 25-39 recruits at a time. Record keeping difficulties precluded obtaining exact age information for the subjects. However, most subjects were between 18 and 22 years old at the time of testing. (Prior to data analysis, data from some subjects were discarded, some for a lack of ability test records, and others for failure to follow task instructions. Finally, because a few subjects had incomplete data (e.g., computer failure, sickness), the degrees of freedom differ by as much as 2 or 3 *df* on some analyses). The final sample size was N = 627.

Procedure

Dispositional measures. As in Experiment 1, individual differences measures of motivation-related dispositions were administered at the onset of the experimental session. In this experiment, subjects were administered 32 items from the ACQ (HAKEMP 88 ACQ; Kuhl, 1985). ACQ items were used to derive two 16-item composite measures of action control orientation (Performance and Failure). Composite scale scores on Control and Stress dimensions of personality were derived from responses to 50 items taken from the Multidimensional Personality Questionnaire (MPQ; Tellegen, 1982). In contrast to Experiment 1, in which subjects responded to MPQ items using a True/False format, instructions accompanying completion of the MPQ items in Experiment 2 told subjects to indicate how descriptive the statement was of them, using a four-point scale ranging from definitely true (1) to definitely false (4).

Choice/simple reaction time testing. This portion of the experiment proceeded exactly the same as in Experiment 1.

Air Traffic Controller Task (general instructions). This portion of the experiment proceeded exactly the same as in Experiment 1.

Minitrial Training. After the initial task instructions, subjects received practice in a series of short, structured task trials. Subjects were shown a series of dynamic task scenarios (presented in real time) and subjects were instructed to perform operations ranging from simple procedures (e.g., "Land plane in 1n (Flt #134) to Runway 1") to more complex procedures (e.g., "Land planes in 3w (Flt #958) and 2n (Flt #440) onto correct runways in the most efficient manner"). An example of a minitrial scenario is shown in **Figure 13** (and can be compared with **Figure 5**, showing the procedural pretraining procedure used in Experiment 1).

The minitrial sequence was similar in some respects to the procedural pretraining program, and in fact, most of the minitrials were derived from the trial scenarios used in the procedural training task. However, in several key facets, the minitrials differed from the procedural pretraining, as follows: (1) Subjects were told "what to do" as opposed to "how to do" the task. Rather than instructing about specific keystroke sequences, the subjects were given an instruction to accomplish the procedure, without a specific direction about how the procedure was to be accomplished; (2) Feedback was ongoing and interactive during the minitrials. If an operational error was made during the minitrial, the subject received a full error message, but was allowed to continue to accomplish the instructions (similar to the full-task) up to the time limit imposed for each minitrial completion; (3) Minitrials were constructed so as to be relatively uniform in difficulty, across trials within a block, and across blocks of trials. Rather than provide scaffolding for the novice subjects (as was done in the procedural pretraining), the minitrials were constructed such that they represented the a similar level of initial challenge associated with confronting a complex, but consistent task; (4) Strict time limits were imposed on each minitrial. Limits were based on a 68*th-percentile* level (based on $z = +.50$) for trial completion for similar subjects in previous pilot testing.

Subjects received seven blocks of 10 trials/block, for a total of 70 minitrials. This sequence typically lasted for a period of 30 - 40 min.

Instructional/Feedback Conditions. A primary aim of this experiment was to investigate the influence of contextually-based self-regulation skill training on ATC task transfer performance. Two forms of self-regulation training were developed using Kuhl's (1985) conceptualization of motivation control and emotion control self-regulation strategies. To assess the impact of the minitrial training alone, a third Control condition was also formed. These conditions are described briefly below.

Control condition. Following the general instructions for the ATC task, subjects received specific instructions for performing the minitrials. Subjects were shown where the specific instructions for actions to be performed in each minitrial were located on the screen, and subjects were then stepped through an example minitrial. Subjects were told to perform the instructions exactly, to work as quickly as possible to avoid reaching time limits for each minitrial, and to notice how to perform various parts of the task while executing minitrial instructions. Subjects were also told that they would receive feedback both during the minitrial (i.e., rule violation error messages), at the end of each minitrial (i.e., correct/incorrect), and at the end of each block of minitrials (i.e., percent correct over the trial block). Subjects were directed to continue the minitrial, even if they committed a rule violation, until they performed the instructed action.

In the Control condition, subjects were given no further instructions. They received unelaborated correct/incorrect feedback following each minitrial, and percentage correct feedback following each trial block.

Emotion Control Condition. In this condition, subjects received the same instructions as in the control condition with the following exceptions. An Emotion Control strategy, emphasizing the focus of attention on positive emotions and the control of negative thoughts, was included in the initial minitrial instructions. Subjects were told to practice the emotion control strategy when performing each minitrial. Emotion control strategy prompts were also provided on a lengthening interval basis in conjunction with individual minitrial feedback. All subjects received three prompts during the first two trial blocks, and two prompts during the remaining trial blocks. The content of emotion control strategy statements was modified over trial blocks so that the most elaborated prompts occurred during the early trial blocks. For example, subjects who performed the sixth minitrial incorrectly were given the following feedback:

Incorrect
Be sure to use the EMOTION CONTROL strategy to avoid negative thinking and to focus your attention on performing the task.

Subjects also received emotion control strategy instructions between trial blocks, (following trial block feedback). Elaboration of these reminders was gradually reduced over trial blocks. For example, prior to the second trial block, subjects received a brief review of the emotion control strategy and instructions to use the strategy during the minitrials. Prior to the final trial block, subjects were simply reminded to use the emotion control strategy.

Motivation Control Condition. Subjects in this condition received the same minitrial instructions as subjects in the Emotion Control condition with two exceptions. First, subjects received motivation control strategy instructions rather than emotion control strategy instructions. Second, in accord with the hypothesized importance of motivation control during later phases of skill acquisition, descriptions of the motivation control strategy, strategy prompts following minitrial feedback, and strategy instructions following trial block feedback were gradually elaborated over the course of minitrial training. (The same interval schedule of elaborated feedback prompts as used in the Emotion Control condition was used in Motivation Control condition). For example, the motivation control strategy description provided to subjects prior to the first minitrial was brief and instructed subjects to give the task their full effort. In contrast, prior to the final minitrial block, the motivation control strategy was more fully described and subjects were instructed to focus maximum effort to the task at all times. For example, subjects who performed the third trial in the sixth minitrial block incorrectly received the following feedback:

Wrong

You landed the plane on a different runway than was instructed.

REMEMBER TO USE THE MOTIVATION CONTROL STRATEGY. Do not permit yourself to reduce your effort or give up. This will interfere with your concentration. Instead, give you full effort to the task at all times.

Immediately following the final mini-trial block, all subjects were administered a brief self-report measure assessing cognitive activities and attentional focus during minitrial training.

Full ATC Task Transfer. Six transfer conditions were created (between-subjects manipulation). These conditions were the result of a full crossing of two variables: *Goal* (No Goal vs. Goal), and Minitrial pre-treatment condition (Control, Emotion Control, and Motivation Control). Thus, the six conditions -- 3 Treatment conditions X 2 Goal conditions -- were as follows:

1. Control Minitrial training -- No Goal (Control) full ATC Task Transfer
2. Control Minitrial training -- Goal full ATC Task Transfer
3. Emotion Control Minitrial training -- No Goal full ATC Task Transfer
4. Emotion Control Minitrial training -- Goal full ATC Task Transfer
5. Motivation Control Minitrial training -- No Control full ATC Task Transfer
6. Motivation Control Minitrial training -- Goal full ATC Task Transfer

No Goal conditions. Following the minitrial training, the No Goal groups received eight, 10-minute task trials. Subjects were instructed to "do your best" prior to each trial. These subjects were told: "*Your objective in the next trial is to get the best performance score you can.*" Immediately following Trials 3, 6, and 8, subjects completed short computerized self-report questionnaires. After the final questionnaire, subjects were debriefed and excused.

Goal condition. The procedure described for the No Goal group was repeated for the three Goal groups (as in Experiment 1) with the following exceptions. Task - specific motivation was manipulated by assignment of a specific and difficult performance goal for all eight full-task trials. Subjects in the Goal conditions received the goal assignment prior to the first full-task trial. Subjects were assigned a cumulative performance score goal of 2100 points for Trial 1. The 2100 - point goal was selected on the basis of results obtained in pilot experiments (no goal) with the ATC task, while also taking into account the additional advantages from the minitrial training (in contrast to the procedural part-task training). Pilot data indicated that 2100 points represented a difficult performance goal (approximately 90*th* percentile) for Trial 1. Subjects in the Goal assignment conditions were told:

> *For the first task trial, you have been assigned a specific performance goal.*
>
> *Your assignment is to reach a PERFORMANCE SCORE OF 2100 POINTS by the end of the trial.*

Subsequent to Trial 1, new goal scores were assigned to the subjects prior to each subsequent trial (Trials 2 - 8). These goal scores increased in accordance with the criterion that the goal remained difficult (again, corresponding to approximately a 90*th* percentile performance level).

In addition to the performance goal assignment, subjects in the Goal conditions were given the opportunity to periodically check their goal progress during the three assigned goal trials. Subjects were told:

> _You can check on how well you are doing by "calling up" more performance information. Several times during the trial, a special signal, (* * * * <F10> * * * *) will appear at the top right of your screen._
>
> _When this signal appears, you may press the F10 key to get more information about how you are doing, relative to your performance goal assignment._

The "F10" signal was displayed for 10 seconds for each minute of each trial (beginning 1:00 min into the trial). Subjects who pressed the F10 key during the signal received a message at the bottom right of their screen indicating the percent of the goal they would obtain. This goal/performance feedback was calculated by extrapolating from the subject's current performance, divided by the assigned goal point total. An example of the message displayed is: "*Based on your current performance you will attain 80% of your goal.*"

Goal subjects also completed three brief questionnaires. The first questionnaire was administered immediately following the first goal assignment, and prior to task Trial 1. The second questionnaire was completed immediately following Trial 3. The third questionnaire was completed immediately following Trial 6.

A final series of post-task questions were administered in a questionnaire that followed the end of Trial 8. These questions addressed a variety of thoughts and reflections regarding the subject's perceptions of the task and their reactions to it. After the final questionnaire, subjects were debriefed and excused.

<u>Emotion Control</u> (No Goal and Goal conditions). Just prior to the start of the first ATC full-task trial, the subjects were given a brief "reminder" to apply the strategy learned

in the minitrial sequence to the full-task environment. They were told:

**** *REMINDER* ****

Use the EMOTION CONTROL strategy while performing the task. That is, do not get upset or worry. Adopt a positive, "CAN DO" attitude. This will improve your performance.

Motivation Control (No Goal and Goal conditions). Just prior to the start of the first ATC full-task trial, the subjects were given a brief "reminder" to apply the strategy learned in the minitrial sequence to the full-task environment. They were told:

**** *REMINDER* ****

Use the MOTIVATION CONTROL strategy while performing the task. That is, keep your effort at a maximum on ALL trials. Adopt a "WILL DO" attitude. This will improve your performance.

Dependent Measures

Three major minitrial performance measures were collected during the pretraining phase of the experiment. These measures were (1) Solution reaction time (RT), which was an estimate of the total time to solve each minitrial item in a trial; (2) Accuracy (an indication of whether the trial was solved correctly or not, within the time allotted); and (3) Keystrokes (in this case, "keystrokes" refers to the number of total keystrokes for a trial minus the optimal number of keystrokes needed to solve the item). Each of the three measures was aggregated to yield average (for RT) or total (Accuracy and Keystroke) variables for each of the 7 minitrial blocks.

Estimates of ability (General and Perceptual Speed), and measures of performance during the full ATC task (landings, errors and keystrokes) were derived in the same fashion as described for Experiment 1.

Minitrial self-report measures. The impact of the instructional training manipulations on self-regulatory activities and attentional focus was assessed using 21, 8-point Likert scale items. Items were derived from self-report measures used in Experiment 1, and were selected on the basis of their ability to provide information on key differences in self-regulatory activities across the three training conditions. Composite scores were obtained for the frequency of evaluation concerns, negative self-reactions, self-motivation, on-task attention, and self-pacing. Internal consistency reliabilities for these composites ranged from r_{xx} = .40 to .78. Three additional items assessed the use of specific strategies for task accomplishment (e.g., "On the hard trials, I made a plan" "I looked for the fastest way to do things,""I imagined myself getting all the problems in the trial correct"). Subjects in the Emotion Control and Motivation Control conditions also completed four items assessing their use of the assigned strategy and their commitment to using the strategy during the full ATC task.

Full ATC Task Self-Report Measures. Goal-related and attentional measures during the full ATC task were the same as those used in Experiment 1 with the following exception. In this experiment goal commitment was assessed using four additional items adapted from the Hollenbeck, Klein, O'Leary, and Wright (1989) Goal Commitment Scale. Internal consistency reliabilities of composite scales for self-regulatory and attentional measures ranged from r_{xx} = .68 to .89.

Results

Minitrial Training Manipulation Checks

Self-report manipulation checks. Subjects in both the Emotion Control and Motivation Control conditions reported moderately high levels of respective strategy use ($M_{\text{Emotion Control}}$ = 12.19; $M_{\text{Motivation Control}}$ =12.55; *2 = Never used, 16=Constantly used*), and intentions to use the strategy during full ATC task performance ($M_{\text{Emotion Control}}$ = 3.66; $M_{\text{Motivation Control}}$ = 3.72; *2= Will definitely use, 16=Will definitely not use*). Results of one way ANOVA showed no significant differences between the two self-regulation training conditions on these measures. These results suggest that the instructional procedures exerted a similar level of influence in the Emotion Control and Motivation Control conditions.

A series of 2 (ability) X 3 (training condition) ANOVAs was conducted to examine the impact of self-regulation manipulations on self-regulatory processes during minitrial training. Results indicated significant main effects of ability on negative self-reactions ($F(1,616) = 14.03, p < .001$), self-pacing ($F(1,616) = 7.25, p < .01$), and use of a speed strategy ($F(1,616) = 11.71, p < .001$). Lower-ability subjects reported more negative self-reactions, a slower pace through the minitrials, and less frequent use of a speed strategy compared with higher-ability subjects. Significant main effects for training condition were obtained on the following measures: negative self-reactions ($F(2,616) = 7.56, p < .001$), fewer performance evaluation concerns ($F(2,616) = 6.71, p < .001$), self-motivation ($F(2,616) = 3.27, p < .05$), and use of a positive imagery strategy ($F(2,616) = 5.26, p < .01$). Consistent with expectations about the influence of emotion control on self-regulation, subjects in the Emotion Control condition reported less frequent negative self-reactions, performance evaluation concerns, and a more rapid pace through the trials than subjects in the Control or Motivation Control conditions. In contrast, motivation control training resulted in more frequent reports of attempts to make oneself try harder and more frequent use of a positive imagery strategy during training compared to self-reports obtained in the Emotion Control and Control conditions. A significant Ability X Training interaction was obtained for reported frequency of planning ($F(2,616) = 4.27, p < .05$). Among lower-ability subjects, those in the Emotion Control condition reported more frequent planning than subjects in the Motivation Control and Emotion Control conditions. Among higher-ability subjects, however, those in the Emotion Control condition reported less frequent planning than subjects in the Motivation Control or Control conditions.

The pattern of results indicated that the two instructional training manipulations did affect the operation of self-regulation components during minitrial training. Moreover, the influence of training manipulation on frequency of using various strategies suggests that alteration of self-regulation processes may be closely associated with specific metacognitive strategies used for task performance. Emotion control self-regulation strategies were posited to reduce attentional resource consumption (e.g., reductions in the frequency of negative self-reactions and performance evaluation concerns). As indicated on the planning strategy measure, this training manipulation were also associated with the more frequent use of (presumably resource-consumptive) planning strategies among lower-ability subjects. The increased use of a positive imagery strategy among subjects in the motivation control condition compared with the other two conditions further suggests that a correspondence between self-regulatory activities and metacognitive performance strategies.

It is also noteworthy that training condition did not exert a significant influence on self-report measures of on-task attention. The absence of training effects on this measure suggests that the effects of the training condition on performance were not likely due to differences in subjects' general attentiveness to the task during minitrial performance.

Minitrial Performance

Ability-Performance results. The first thing to note from this experiment is that the less-structured nature of the minitrial environment (in comparison to the procedural pretraining manipulation used in Experiment 1), resulted in rather strong demands on the General ability to perform well (the main performance criterion for was RT for the minitrials). In the control condition, the initial correlation between General ability and minitrial task performance was $r = .502$, a value very nearly equivalent to that shown in the first full-task trial in Experiment 1 (see **Figure 14**). However, as with any novel, but consistent task, the association between General ability and task performance attenuated as skill increased in the minitrial practice sequence. At the end of the 7 minitrial practice blocks, the correlation between General ability and performance was $r = .276$. As with previously discussed motivational manipulations, the Emotion Control and Motivation Control procedures resulted in an attenuation of General ability - performance associations, though the Emotion Control condition showed a more pronounced decline in ability requirements than did the Motivation control condition. At the end of practice in the minitrial sequence, all three conditions showed roughly equivalent modest correlations between performance and the General ability composite.

The correlations between Perceptual Speed ability and performance (see **Figure 14**) demonstrated that subjects in the Emotion Control condition proceeded to the second stage of skill acquisition in a more pronounced fashion than the other two conditions, a finding that mirrors the results from manipulation used within the full-task training in Experiment 1.

In summary, based on both the General and the Perceptual Speed ability - performance correlations, the minitrial sequence showed a clear indication of an initially difficult task that became less demanding during practice.

Behavioral Measures -- Raw Task Performance

Cumulative RT. A repeated-measures ANOVA was derived for the Reaction Time measures, is shown in **Table 2**. Consistent with performance measures from the full ATC task (in Experiment 1, and with earlier investigations), the RT measures showed three major effects. First of all, a strong ability effect was observed, with higher-ability subjects performing more quickly than lower-ability subjects. Also, a main effect of practice trials was observed, along with a convergence of higher and lower-ability subjects on RT performance (evidenced by the significant Ability X Trial interaction term). These results support the hypothesis that the minitrials were initially demanding on attentional/cognitive resources, but that such demands attenuated with continued practice.

Accuracy. The correctness of performance on the minitrials (a dichotomous variable for each minitrial) mirrored the information from the RT measures. That is, Ability, Trials, and the Ability X Trials interaction term indicated large initial differences between higher and lower-ability subjects, but these became substantially attenuated with practice.

Keystrokes. The "Keystrokes" variable from the minitrial training sequence has a somewhat different meaning from the keystrokes variable collected in the full ATC task. Given the highly prescribed task instructions (e.g., Land Plane in 3e on Runway 1), it was possible to compute the optimal number of keystrokes for each trial, to serve as the baseline for actual performance efficiency. Positive numbers for keystrokes indicate the number of keystrokes used *over and above* the optimal number of keystrokes (a *direct* measure of performance efficiency). The ANOVA results for this measure indicated main effects for Treatment, Ability, and Trials. These results (shown graphically in **Figure 15**, and numerically in **Table 2**), indicate that, in contrast to the full ATC task, higher-ability subjects performed *fewer* keystrokes than their lower-ability counterparts (in this case, meaning a higher efficiency index for the higher-ability subjects). Although there was a significant Trial effect as well (most likely due to the different types of trial content rather than an effect of practice, per se), no convergence between higher and lower-ability subjects was noted.

Finally, the significant main effect of minitrial Treatment is evident in **Figure 15**. As the figure shows (for both higher and lower-ability subjects), the Motivation Control condition led to a *decrease* in efficiency (more keystrokes) in comparison to the Control condition, while the Emotion Control condition led to an overall increase in efficiency (fewer keystrokes). The comparative differences in activity level/efficiency are concordant the theoretical basis of these instructional manipulations. That is, by increasing the effort demands on the subjects (Motivation Control) or decreasing the demands (Emotion Control), the overall activity level (and thus the efficiency with which the minitrials were performed) was affected. These effects seem especially salient in view of the fact that no *treatment*-based differences in Accuracy or cumulative RT variables were found in these analyses. (The usual caution here should be noted with respect to affirming the hypothesis of null effects from the RT and Accuracy analyses, though given the large sample sizes under investigation here, such a conclusion is reasonable.)

Full-Task Performance. For the analysis of full ATC task results, it is important to keep in mind that there are two elements of transfer-of-training under investigation here. The use of the minitrial procedure provided a basis for examining *near* transfer effects, from a task-relevant content perspective. The Control and Goal conditions provide the conditions that allow examination of these general transfer effects. In addition, given that the Emotion Control and Motivation Control manipulations took place *within* the minitrials (and not directly in the full ATC task), further examination of transfer, from a self-regulation perspective is possible. As such, the results will be presented with respect to these two interrelated, but separable issues.

Ability-Performance Results. The first examination of transfer-of-training results concerns the Control and Goal conditions. The correlations between General and Perceptual Speed ability composites with task performance (Landings) are presented in **Figure 16**. While there is a qualitative similarity between these correlational results and those from the analogous conditions from Experiment 1, it is important to note that the minitrial pretraining resulted in a substantial attenuation of demands on General ability, for both conditions (for the Control condition in Experiment 1, Trial 1 General ability - performance association was $r = .485$, for Experiment 2 it was $r = .211$ ($z = 5.48$, $p < .01$). Furthermore, both Control and Goal conditions showed elevated correlations between Perceptual Speed ability and task performance, a finding consistent with the notion that the minitrial practice was more effective in developing ATC task skills.

For the two Emotion Control conditions (see **Figure 17**), General ability - performance correlations were attenuated in comparison to the Control conditions, and were essentially equivalent to one another. In addition, the presence or absence of a goal had little effect on ability-performance correlations, consistent with the hypothesis that the Emotion Control condition acts as a "buffer" or "protection" against the deleterious effects of the goal during initial task engagement.

The Motivation Control conditions, while showing equivalent attenuated General ability-performance correlations early in full task performance (see **Figure 18**), show some small divergence with increased practice, with the Goal condition leading to slightly higher demands on General ability during the last few task trials. In addition, the Goal condition led to an increase in Perceptual Speed ability - performance correlations throughout practice. Again, these results are consistent with a positive transfer of initial training, in that the goal was expected to exacerbate the cognitive demands on the subjects, especially at the later trials (consistent with the minitrial instructions to subjects to "make a special effort" to keep their effort levels high when the task becomes easier to perform over practice). That is, the expected effect of the motivation control/goal condition was to accentuate the ability-performance correlations, especially in later trials, an expectation that was largely borne out in these analyses.

Raw task performance results. The direct performance measures discussed here are the same as those discussed in Experiment 1. They pertain to the number of planes landed (Landings), errors made (Errors), and total keystrokes (Keystrokes) in each of the 8 full ATC task trials.

Planes Landed. A repeated-measure ANOVA was performed on Landings. The results of this analysis are presented in **Table 3**, and the salient effects are illustrated in **Figure 19**. The most prominent result from these analyses was the substantial overall improvement in task performance at the first full-task transfer trial, in comparison to the procedural part-task training used in Experiment 1 and in previous investigations. Even though the minitrial training comprised a nearly equivalent amount of training time to the procedural pretraining (approximately 30 minutes), subjects were performing as well on the first full task trial subsequent to minitrial training (M = 33.28 planes landed), as on the *3rd* full-task trial subsequent to procedural part-task training (M = 37.16 planes landed) -- see **Figure 10** for a comparison figure from Experiment 1. Although the initial full-task trials showed the largest differences between the two procedures, both higher and lower-ability subjects receiving minitrial pretraining performed at levels superior to those in the procedural pretraining conditions, even after 8 full-task trials. The advanced level of performance shown in group means is entirely consistent with the attenuated General ability - performance correlations discussed earlier.

In addition to the overall benefits of minitrial training, the ANOVA revealed that the general factors found in other learning tasks were also found in the full-task transfer. That is, significant effects of Ability and Trials were found (while no additional convergence of higher and lower-ability subjects were found (i.e., the Ability X Trials interaction was not significant). Furthermore, a significant interaction was found for the Trials X Goal effect. As illustrated in the three panels of **Figure 19**, the effect of Goal manipulation was *emergent* (consistent with findings reported in Kanfer and Ackerman, 1989(a)). Although the effect sizes were too small to be significant (F = 1.22, ns.), the data show a trend in support of a modest Treatment X Goal interaction. That is, there is a trend for the goal to be somewhat deleterious to task performance in the Control conditions, modestly effective (or ineffective) in the Emotion Control condition, and most effective (especially at late task trials) in the Motivation Control condition. That this effect was not significant is a concern, but is attributable to the restricted range in associated with the high levels of task performance resulting from the highly effective minitrial training. Nonetheless, the trend seems evident to a casual Bayesian analysis, even if the Pearsonian statistics do not support a decisive conclusion to be made for this particular set of effects.

Errors. The analysis of errors yielded results that were generally consistent with the results from previous investigations, and from the analysis of Landings. That is, significant effects were found for Ability, Trials, and Ability X Trials (a convergence of higher and lower-ability subjects), as shown in **Table 3** and **Figure 20**. However, the additional Trials X Treatment X Ability effect again points to the conclusion that the effects of the various treatments were to be found more in strategy development and application than in the most salient measure of task performance (i.e., Planes Landed). As the figure shows, there are two elements to this latter significant interaction. First of all, lower-ability subjects in the Emotion Control conditions showed a decreased number of errors, relative to the Control and Motivation Control conditions, although this advantage largely washed as the subjects in the other conditions improved with practice. On the other hand, in the higher-ability group, the Motivation Control conditions resulted in attenuated number of errors at the end of practice. Again, these data clearly support the notion that the Emotion Control manipulation (during the minitrial practice) led to a positive impact for lower-ability subjects during early stages of task engagement, and the Motivation Control condition led to a positive impact on higher-ability subjects at the later stages of skill acquisition.

Keystrokes. There were no surprising effects to be found in the keystrokes analysis (see **Table 3** and **Figure 21**). As with Experiment 1, significant main effects of Ability (higher-ability had more keystrokes than lower-ability subjects), Trials (an increase in keystrokes with task practice), and a significant interaction effect of Trials X Ability (divergence of higher and lower-ability subjects with practice) were found. No direct comparison with the combined Emotion/Motivation Control group in Experiment 1 was possible, given that that particular condition was not investigated in Experiment 2.

Self-report measures - Goal related measures. Results of a 2 (ability) X 3 (training) ANOVA for self-report measures of goal commitment among Goal condition subjects revealed no significant main or interaction effects. Overall, subjects reported a similar, high levels of goal commitment prior to Trial 1 (M = 34.30; *5= extremely uncommitted; 40 = extremely committed)* and prior to Trial 4 (M = 33.70). A significant main effect for training was obtained on self-confidence for goal attainment prior to Trial 1 ($F(2,297) = 4.78$, $p < .01$). Subjects in the Control minitrial training condition reported less self-confidence than subjects in the Emotion Control and Motivation Control training conditions. However, the impact of training condition attenuated over trials such that no significant main or interaction effects were obtained in ratings of self-confidence prior to Trial 4. These results suggest that subjects did not differ in their motivation for goal accomplishment.

Although subjects did not differ in willingness to accomplish the assigned goal, examination of self-report measures of goal attentiveness taken after Trial 3 and again after Trial 6 indicated significant main effects for ability and training on the reported frequency of attention to the goal assignment during ATC performance. Significant main effects for ability obtained after Trial 3 ($F(1,297) = 4.88$, $p < .05$) and after Trial 6 ($F(1,297) = 4.13$, $p < .05$) indicate that lower-ability subjects reported a higher level of attention to the goal assignment compared to higher-ability subjects. Similarly, a significant main effect for training condition was obtained after Trial 3 ($F(2,297) = 4.45$, $p < .05$) and a marginally significant training effect after Trial 6 ($F(2,297) = 2.85$). Consistent with hypothesized predictions, subjects in the Emotion Control training condition reported less frequent attention to the goal assignment than subjects in the Motivation Control and Control training conditions. Since training in the Motivation Control condition focused on increasing attentional effort, rather than reducing negative emotions, these subjects were not expected to differ in level of goal attentiveness compared to the Control training conditions.

Taken together, these results provide considerable evidence for the expected transfer of training on targeted self-regulatory processes. The attenuated effects of training condition on goal attentiveness following Trial 6 must further be considered in light of the criterion measures used and the content of training. In the Emotion Control training condition, subjects were instructed to avoid negative emotions that distracted them from the task. During the early phase of skill acquisition, goal attentiveness is hypothesized to trigger resource-consumptive negative self-reactions. Self-regulation processes aimed at emotion control were thus expected to reduce the frequency of goal attentiveness as a strategy for reducing the frequency of negative self-reactions. During later phases of skill acquisition, however, goal attentiveness is less likely to trigger negative self-reactions due to improvements in performance. As a consequence of the weakened association between goal attentiveness and negative self-reactions, persons may focus on the goal as a strategy for redirecting spare attentional effort back to the task. As such, the attenuated influence of training condition on goal attentiveness may be best understood, not as failure to transfer, but rather as reflecting the lessened importance of emotion-based self-regulation during intermediate phases of complex skill acquisition.

<u>Self-report measures - Attentional measures</u>. A series of 2 (ability) X 3 (training) X 2 (goal) ANOVAs conducted on self-report measures of attentional focus during the final three ATC task trials assessed the impact of minitrial training on cognitive activities. Significant main effects for training condition were obtained on frequency of negative self-reactions $F(2,597) = 4.72$, $p < .05$) and negative affect ($F(2,597) = 10.24$, $p < .05$), and a marginally significant main effect for training was obtained on frequency of performance evaluation concerns ($F(2,597) = 2.66$). Subjects in the Emotion Control training condition reported less frequent negative self-reactions, less frequent negative affective thoughts, and less frequent thoughts concerning performance evaluation compared with subjects in the Control and Motivation Control training conditions. These results are consistent with predictions derived from the integrated resource allocation model.

In addition, significant main effects for ability was also obtained on these measures: negative self-reactions ($F(1,597) = 6.77$, $p < .01$), negative affect ($F(1,597) = 10.24$, $p < .001$, positive affect ($F(1,597) = 4.72$, $p < .05$, and self-motivation ($F(1,597) = 5.22$, $p < .05$). As expected, lower-ability subjects reported a more disruptive pattern of attention during task performance than higher-ability subjects; namely, more frequent negative self-reactions, more frequent negative affect, and fewer self-directions to try harder. Unexpectedly, lower-ability subjects also reported more frequent positive self-reactions than higher-ability subjects. No other significant main or interaction effects were obtained on attentional measures.

Discussion

The first thing to be noted about the results of Experiment 2 was the high degree of effectiveness of the minitrial training on full ATC task transfer. In general, 30 - 40 minutes of training using the minitrial procedure was equivalent to performance after both 30 minutes of procedural pretraining *plus* another 30 minutes of full ATC task transfer. The increased difficulty of the minitrials was reflected in the initially high correlations between general ability and minitrial performance. However, the ability demands of the minitrials attenuated with practice, such that, by the time subjects were transferred to the full ATC task, the ability demands of both the minitrials and the full ATC task were diminished.

Although the minitrial procedure provided a powerful training environment, the addition of Emotion Control and Motivation Control training also had an impact on the role of abilities in determining individual differences in minitrial task performance. The Emotion Control training especially showed the diminution of General ability demands, and the increase in Perceptual Speed ability demands associated with development of proceduralized knowledge. In addition, the Emotion Control training resulted in increased efficiency in keyboard usage during initial minitrial training, especially for the lower-ability subjects. This set of results mirror those from the embedded Emotion Control training given in Experiment 1 (even though *no* goals were assigned in the minitrial procedure)

Given the effectiveness of the minitrial training, it was predictable that the Control condition showed attenuated General ability - performance correlations at the first full-task transfer trial. Nonetheless, the Goal condition showed an even greater attenuation in these ability-performance correlations, a feature that was maintained across all subsequent full-task trials. On the one hand, the Emotion Control training manipulation again resulted in a deflection of the impact of goals; no differences were found for ability-performance relations between the Goal and No Goal conditions. On the other hand, the Motivation Control condition was affected in the opposite fashion of the Control conditions. That is, the imposition of the goal heightened the impact of the Motivation Control training on later full-task ability-performance correlations. For this manipulation, the presence of a Goal increased both General ability - performance and Perceptual Speed ability - performance correlations with performance, especially at the later stages of practice (which corresponded to the instructions from the minitrials).

In addition to mediating the ability-performance relations, transfer effects were found for mean performance, for self-regulatory behavior, and for strategy development. The provision of a goal was ineffective for average performance in the Control training conditions (or may have been slightly detrimental), and was beneficial for the Motivation Control condition, especially at late stages of practice. Indeed, for all conditions, the benefits of specific goal assignments were observed as emergent as practice proceeded in the full ATC task.

Although the Emotion Control training did not transfer to direct benefits on the number of planes landed during the full task, the training clearly had a positive effect on strategy for lower-ability subjects, early on in transfer task performance (namely, in the reduction of error rates). In contrast, for the Motivation Control conditions, the transfer of training instruction was found to be most effective, for the higher-ability subjects, most notably in the reduction of error rates at advanced practice trials. Finally, subjects reported that they used the previously trained strategies of Emotion Control and Motivation Control, even in the presence of competing demands imposed by the goal provision.

IX. GENERAL DISCUSSION

The theoretical perspective and the two sets of empirical investigations support and extend the basic framework delineating the independent and interactive effects of abilities and self-regulatory processes during skill acquisition. The demonstration of these effects, in embedded self-regulation training and in a training and transfer procedure, lend further support to the proposition that self-regulation involves at least two component trainable skills, those of emotion control and motivation control. Training for these two components yielded a variety of performance and perception effects, as well as interacting with the dynamic effects of the cognitive ability determinants of individual differences in skill acquisition. The general effects are summarized below.

Goal assignments for complex, but consistent skill learning tasks yield both costs and benefits to task performance. Specifically, goal assignments are initially deleterious to task performance, especially when the task is novel, and when earlier acquisition of declarative knowledge about the task is limited. However, once skills have been developed beyond the initial stage of skill acquisition, the effect of a difficult, specific goal is generally beneficial to task performance, first to the higher-ability subjects (who acquire proceduralized knowledge faster than their lower-ability counterparts), and then later to lower-ability subjects (after they have reached later stages of skill acquisition). As such, the current investigation replicated and extended earlier findings concerning the dynamic costs and benefits of goal assignment during skill acquisition.

Two components of the self-regulatory system have important and separable effects on task performance and metacognitive strategy development, in the presence and in the absence of assigned performance goals. When training of emotion control skills was provided, the detrimental effects of goals were attenuated for all subjects initially, and for lower-ability subjects during early skill development. On the other hand, training on motivation control skills led to an intensification of goal effects (when a goal was assigned). Thus, the benefits that accrue from motivation control training are found primarily among the higher-ability subjects (or to lower-ability subjects *late* in skill acquisition). In the absence of a goal, training of motivation control had little cost in terms of depressed performance for lower-ability subjects. Combining the training of emotion control and motivation control (as in Experiment 1) had effects that appear to have been complementary or detrimental, depending on the timing of training vis à vis skill development. When insufficient acquisition of declarative knowledge preceded the instigation of motivation control training, increased effort-driven activity was not accompanied by increased performance. It seems clear that future investigations should focus on optimizing the impact of these two training methods, in accordance with learner readiness.

The overall effects of self-regulation training were consistent with our theory-based hypotheses. Lower-ability learners are most benefitted by training in emotion control aspects of self-regulation, especially when they are most likely to become frustrated by the demands imposed by a novel and complex task. Higher-ability learners are most benefitted by training in motivation control, especially when they are most likely to become complacent with their skilled levels of task performance.

The effectiveness of the embedded training demonstrated in the first experiment allows a conclusion that these components of self-regulation are partly learnable (or skill-based). That these training procedures also resulted in substantial transfer in the second experiment provides support that these self-regulatory skills are potentially stable and generalizable. Moreover, the finding that even on transfer, self-regulatory training leads to changes in ability-performance relations strongly indicates that the learning process is a dynamic interplay between the attentional demands of the task, the ability levels of the learners, and the level of self-regulatory skill. These interactions lead, first of all, to the possibility of training interventions at remediation. However, the dynamic relations between ability and motivational/metacognitive processes during skill acquisition imply that prediction of individual differences in performance during various stages of skilled performance may be enhanced by a consideration of abilities in the context of self-regulatory and metacognitive skills.

Future research is expected to be devoted to providing structured remediation of self-regulatory skills, both in embedded training situations, but also in the domain of training outside of specific task situations (for distant transfer). Further, the results of the current investigation have pointed to the importance of assessment of strategy development as an expression of self-regulation. Future investigations are planned to focus more specifically on strategy development, in an effort to especially understand and control the manifestations of motivation control. In addition, it will be important to evaluate the persistence of the benefits associated with self-regulation skill training. Planning is in progress to consider more complex tasks, those spanning a longer training program, and skill retention issues.

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XI. PUBLICATIONS AND PRESENTATIONS DURING GRANT PERIOD

Publications

Ackerman, P. L. (1989). Individual differences and skill acquisition. In P. L. Ackerman, R. J. Sternberg, & R. Glaser (Eds.). *Learning and individual differences: Advances in theory and research* (pp. 165-217). New York: W. H. Freeman.

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Ackerman, P. L. (1990). Coffee, tea, . . . or tragedy? A review of E. L. Wiener & D. C. Nagel (Eds.) (1988). *Human factors in aviation. Contemporary Psychology, 35,* 394-395.

Ackerman, P. L. (In press). A correlational analysis of skill specificity: Learning, abilities, and individual differences. *Journal of Experimental Psychology: Learning, Memory, and Cognition.* (to appear September, 1990)

Ackerman, P. L. (In press). Human Intelligence. Chapter in S. C. Shapiro (Ed.) *Encyclopedia of Artificial Intelligence. Volume 1, 2nd Edition.* New York: Wiley. (Revision and expansion of Ackerman, 1987.)

Ackerman, P. L. (Ed.) (In press). Frontiers of learning and individual differences: Paradigms in transition. Special issue of *Learning and Individual Differences: A Multidisciplinary Journal in Education.*

Ackerman, P. L., & Humphreys, L. G. (In press). Individual differences theory in industrial and organizational psychology. Chapter to appear in M. D. Dunnette (Ed.) *Handbook of industrial and organizational psychology, Volume 1. Theory in industrial and organizational psychology.* Palo Al. `, CA: Consulting Psychologists Press.

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Paese, P. W., Lind, E. A., & Kanfer, R. (1989). Procedural fairness and work group responses to performance evaluation systems. *Social Justice Research*, 2, 193-205.

Conference Presentations

Ackerman, P. L. (1989, March). *Cognitive abilities, skill learning, and transfer of training.* Symposium paper presented at the 1989 annual meeting of the American Educational Research Association, San Francisco, CA.

Ackerman, P. L. (1989, November). *Test practice and task practice: A dynamic ability-skill framework.* Paper presented at the 1989 annual meeting of the Psychonomic Society, Atlanta, GA.

Ackerman, P. L. (1990, August). Symposium on *Selection of air traffic controllers: complexity, requirements and public interest*. Symposium discussant. To be presented at the 1990 annual meeting of the American Psychological Association, Boston, MA.

Ackerman, P. L., & O'Brien, E. A. (1990, August). *Automaticity theory and fine motor coordination: Controlled, automatic, or semi-automatic processes*. Symposium paper to be presented at the 1990 annual meeting of the American Psychological Association, Boston, MA.

Kanfer, R. (1989, March). *Conation and cognition: An interactionist approach to skill learning*. Symposium paper presented at the annual meeting of the American Educational Research Association, San Francisco, CA.

Kanfer, R. (1989, April). Panel participant in *Control theory Perspectives: A debate*. Paper presented at the annual meeting of the Society of Industrial and Organizational Psychology, Boston, MA.

Kanfer, R. (1989, August). Symposium discussant in *Commitment and Turnover*. Paper presented at the annual meeting of the Academy of Management, Washington, D.C.

Kanfer, R. (1990, April). Symposium discussant in *Motivation, Volition, and Individual Differences*. Presented at the annual meeting of the American Educational Research Association, Boston, MA.

Kanfer, R. (1990, April). *Motivated cognition and cognitively-based motivation: An integrated resource allocation approach*. Presented at the annual meeting of the Society of Industrial and Organizational Psychology, Miami Beach, FL.

Kanfer, R., Dugdale, B., Nelson, L., & Ackerman, P. L. (1990, April). *Goal setting and complex task performance: A resource allocation perspective*. Presented at the annual meeting of the Society of Industrial and Organizational Psychology, Miami Beach, FL.

Ackerman, P. L., & Kanfer, R. (December, 1989). *An integrated selection/skill-training approach to enhancing Air Traffic Controller performance*. Presentation to the Mid-America Aviation Resource Consortium Aviation Education Standing Committee, St. Paul, MN.

Invited Addresses

Ackerman, P. L. (1989, May). *Learning and individual differences: Eighty years of research and still going strong*. Invited colloquium presented to the School of Psychology, Georgia Institute of Technology, Atlanta, Georgia.

Ackerman, P. L. (1989, August). *Abilities and individual differences in skill acquisition: Theory and applications.* Invited address (Divisions 21 & 1) presented at the annual meeting of the American Psychological Association, New Orleans.

Ackerman, P. L. (1989, August). *Abilities and skills: A framework for learning and individual differences.* Invited Early Contribution Award in Educational Psychology Address (Division 15). Presented at the annual meeting of the American Psychological Association, New Orleans.

Ackerman, P. L. (1989, September). *Learning and individual differences: A cognitive ability and skill framework.* Invited colloquium presented to the Department of Psychology, North Dakota State University, Fargo, North Dakota.

Ackerman, P. L. (1990, April). *Abilities and individual differences in skill acquisition: Theory and applications.* Invited colloquium presented to the Department of Psychology, University of Texas, Austin, Texas.

Ackerman, P. L. (1990, April). *Predicting individual differences in performance during skill acquisition: A view from the trenches.* Invited colloquium presented to the U.S. Air Force Human Resources Laboratory, San Antonio, Texas.

Kanfer, R. (1989, May). *Motivation and self-regulation in skill acquisition: From videogames to real-world tasks.* Invited address, Midwestern Psychological Association meeting, Chicago, IL.

Kanfer, R. (1989, November). *A self-regulation perspective for selection and training of Air Traffic Controllers.* Invited talk, Civil Aeromedical Institute, FAA, Oklahoma City, OK.

Kanfer, R. (1989, November). *Motivation and self-regulation: A resource allocation perspective.* Invited colloquium, Tulane School of Business, Tulane University, New Orleans, LA.

Kanfer, R. (1989, November). *A conative-cognitive framework for learning and performance.* Invited colloquium, Department of Psychology, Georgia Institute of Technology, Atlanta, GA.

Kanfer, R. (1990, April). *Motivation Theory: New approaches to old and new problems.* Master Tutorial presented at the annual meeting of the Society of Industrial and Organizational Psychology, Miami Beach, FL.

Kanfer, R. (1990, June). *Ushering in a new era in motivation theory and research.* Invited talk to the Personnel Research and Human Resources Research Group, College Park, MD.

XII. APPENDIX. THE KANFER-ACKERMAN ATC TASK

Previous approaches to studying ability and motivational determinants of skill acquisition have tended to concentrate on relatively simple perception, memory, and psychomotor tasks (e.g., addition tasks). Although such tasks are tractable from a components of information processing perspective, these tasks do not permit examination of ability or motivational determinants of skill acquisition in task environments characterized by gradual accretion of component skills. The ATC task was developed to provide a task environment that allows for flexibility in strategy tryout and the sharing of attention among task components and metacognitive activities.

The ATC task is a rule-based, real-time, computer-driven task that simulates some of the activities performed by air-traffic controllers. The overall objective for learners was to land planes safely and efficiently. An example of the ATC task display is presented in **Figure A-1**. As shown, the following task elements are displayed when performing the task: (a) four runways, (b) 12 hold pattern positions, and (c) a queue stack with asterisks indicating planes requesting permission to enter the hold pattern. Two runways run North-South; two runways run East-West. One North-South and one East-West runway is short; one North-South and one East-West runway is long.

The hold pattern, located in the middle right section of **Figure A-1**, contains twelve hold pattern positions, divided into three levels (analogous to three platters at different altitudes in the sky over the airport). Hold pattern position is indicated by number and letter in the Position (POS) column. Level 1 hold positions had the lowest altitude (i.e., closest to the ground) and Level 3 hold positions had the highest altitude (i.e., were furthest from the ground). Four positions, corresponding to the points of the compass (i.e., N, S, E, W), were available in each level.

Planes are admitted to the hold pattern from the queue stack. The queue, located at the upper right of the screen, displays planes requesting permission to enter the hold pattern. Each plane request was represented by an asterisk. Planes enter the queue at the rate of one every 7 seconds. Plane requests remain in the queue until the learner places the plane in the hold pattern.

Plane information is displayed in the hold pattern. As shown in **Figure A-1**, four types of planes enter the learner's hold pattern; 747's, 727's, DC10's, and Props. When a plane is placed in the hold pattern, Flight Number (FLT#), Plane Type (TYPE), and Number of Minutes of Fuel remaining (FUEL) are displayed. Within each trial an approximately equal number of plane types are randomly drawn from the queue. Fuel remaining is determined when the plane is brought into the hold pattern, is randomly varied from four to six minutes. Once the planes enter the hold pattern, fuel remaining decreases in real time, such that when zero minutes of fuel remain, the plane crashes.

```
FLT#      TYPE      FUEL      POS.
----      ----      ----      ----      Score    :  150
                               3 n      Landing Pts:  150   Penalty Pts:    0
                               3 s      Runways : DRY
 161       747        5        3 e      Wind     : 40 - 50 knots from SOUTH
                               3 w
 403       747        6        2 n      Flts in Queue: ...
 889       727        6        2 s             <F1> to accept
                               2 e
                               2 w
 631       727        6        1 n             Winds 40-50 knots
 144       prop       5        1 s             Winds from South
 903       DC10       6        1 e             Runways dry
 122       747     *  3        1 w

===========================  s   #1 <-

=========727======           s   #2

|||||||||||||||||||||||||||  e   #3

|||||||||||||||||||          e   #4
                                         Can use short runways when:
                                     747 - Never            Prop - Always
                                     DC10 - Not Icy & not 40-50 knots
                                          727 - Dry or 0-20 knots
```

Figure A-1. Static Screen Display of the Kanfer-Ackerman Air Traffic Controller Task.

Learners also receive information on airport weather conditions. Weather information is used (in accordance with the rule set) to determine what planes are allowed to land on which runways. Weather conditions are comprised of three elements; wind speed, wind direction, and ground condition. Wind speed and wind direction information is displayed on the "wind" line at the top right corner of the screen. Ground condition is displayed on the "runways" line. Updates to weather conditions are displayed throughout each task trial. Three types of wind speed are presented (0 - 20 knots, 25 - 35 knots, and 40 - 50 knots). Four types of wind direction are displayed (North, South, East, and West). Three levels of ground conditions are used (runways dry, wet, or icy). Changes in weather conditions (defined as a change in at least one of the three weather condition components) is varied randomly during a task trial. On average, these changes occur about twice a minute (i.e., 20 weather changes are initiated during each 10-minute task trial).

Feedback/Knowledge of Results. The first component of knowledge of results is the one-to-one mapping between keystrokes made by the learner, and operation of a cursor on the screen. As planes are selected, various parts of the display are highlighted. When a plane is moved from one hold position to another, or to a runway, the learner sees an analogous change to the display. Learners also receive three types of continuously updated performance information throughout each trial. Cumulative performance (Score) for the current trial is based upon a specified point scheme. Learners receive 50 points for each plane successfully landed. Ten points are deducted for each technical error made (violation of the rules). One hundred points are deducted from the performance score for each plane that runs out of fuel in the hold pattern (i.e., plane crashes). Performance scores can be negative or positive depending on how many planes are landed, relative to number of errors made and planes crashed. In addition, learners receive separate landing (Landing Pts.) and error (Penalty Pts.) information. Landing Pts. are based upon the number of planes landed. This score starts at zero and increases by 50 points for each plane landed. Penalty Pts. reflects the number of rule violations and plane crashes. This score starts at zero and decreases for each error. All learners are informed of the point scheme in the initial task instructions.

Task Rules. For the experiments described below, six rules govern task performance (shown in **Figure A-2**). These rules describe the conditions required for successful manipulation of planes. When learners perform actions that do not comply with a rule, the action command is ignored, an error message is presented on the screen indicating which rule is violated, and 10 points are deducted from the cumulative and penalty point scores. Rules 1 and 4 describe weather condition rules for landing planes onto runways. Rule 2 requires that plane landings must be initiated from one of the four hold pattern positions in Level 1. Rule 3 describes the rule governing movement of planes within the hold pattern. Rule 5 requires that planes with 3 or less minutes of fuel left must be landed immediately. A warning asterisk is displayed next to the FUEL value when remaining fuel fell below four minutes (e.g., see FLT # 122 in **Figure A-1**). If the plane is not landed prior to a FUEL value of 3, a 10-point penalty is incurred for each minute that learners failed to land the plane. Rule 6 requires that only one plane occupy a runway at any time.

RULE		KEYWORD
RULE 1:	PLANES MUST LAND INTO THE WIND. (That is, if the wind is from the South, the plane must be landed on a n-s runway)	[DIRECTION]
RULE 2:	PLANES CAN ONLY LAND FROM LEVEL 1.	[LEVEL]
RULE 3:	PLANES IN THE HOLD PATTERN CAN ONLY MOVE 1 LEVEL AT A TIME, BUT TO ANY AVAILABLE POSITION IN THAT LEVEL.	[HOLD]
RULE 4:	GROUND CONDITIONS AND WIND SPEED DETERMINE THE RUNWAY LENGTH REQUIRED BY DIFFERENT PLANE TYPES. [ALL PLANES CAN USE LONG RUNWAYS.] IN PARTICULAR: 747's ALWAYS REQUIRE LONG RUNWAYS. DC10's CAN USE SHORT RUNWAYS ONLY WHEN RUNWAYS ARE DRY OR WET AND WIND SPEED IS LESS THAN 40 KNOTS. 727's CAN USE SHORT RUNWAYS ONLY WHEN THE RUNWAYS ARE DRY OR WIND SPEED IS 0 - 20 KNOTS. PROP's CAN ALWAYS USE SHORT RUNWAYS.	[LENGTH]
RULE 5:	PLANES WITH LESS THAN 3 MINUTES FUEL LEFT MUST BE LANDED IMMEDIATELY.	[FUEL]
RULE 6:	ONLY ONE PLANE AT A TIME CAN OCCUPY A RUNWAY.	[OCCUPIED]

Figure A-2. ATC Rule Set.

All rules, except Rule 4, describe simple, non-contingent conditions governing task performance. In contrast, Rule 4 describes a plane-contingent rule that involves both simple and complex elements (i.e., the specific ground and wind-speed conditions that must be met for landing each plane type on short and long runways). Simple, non-contingent elements of this rule address landing requirements for 747 and Props (747's can never land on short runways; props can always land on short runways). For 727's, a disjunctive rule relating wind and ground conditions regulates when these plane types can land on short runways. For DC10's, a conjunctive wind and ground condition rule for short runway usage is imposed. Since positive task performance is based upon number of plane landings, it was to the learner's advantage to use both long and short runways simultaneously. Knowledge of the complex rules that govern when 727's and DC10's may use a short runway is thus an important determinant of skilled performance.

Learners are provided with the opportunity to call-up brief descriptions of each rule throughout all task trials. Learners are instructed to press a key corresponding to the rule they wished to view. The requested rule appears on the lower right corner of the screen for 10 seconds. Learners may call-up any of the rules as many times as they wished during task trials. Note, however, that calling-up a rule does not stop the simulation.

Figure A-3 displays an example of the error messages. Error messages, which are displayed in the lower right hand section of the screen, appear immediately following a rule error or plane crash. Error messages were displayed for 10 seconds.

The task requirements. Three principal actions are performed by learners: (1) accepting planes into the hold pattern, 2) moving planes in the three-level hold pattern, and 3) landing planes on appropriate runways. Learners manipulate planes using only four keys on the computer keyboard (plus keys for rule call-ups). For example, planes were moved down the hold pattern by pressing the "down-arrow" key once for each position in the hold pattern. A one-to-one correspondence between keyboard and screen actions was maintained by linking each keyboard response to movement of a small cursor arrow on the screen (see the "<—" symbol in **Figure A-3**). Specific keyboard actions taken to move a plane in the hold pattern and to place a plane on a runway resulted in highlighting of the target plane and real-time movement of the plane across the runway. Successful performance on this task requires knowledge of the rules governing plane movements and landings as well as knowledge about how to make plane movements using the computer keyboard.

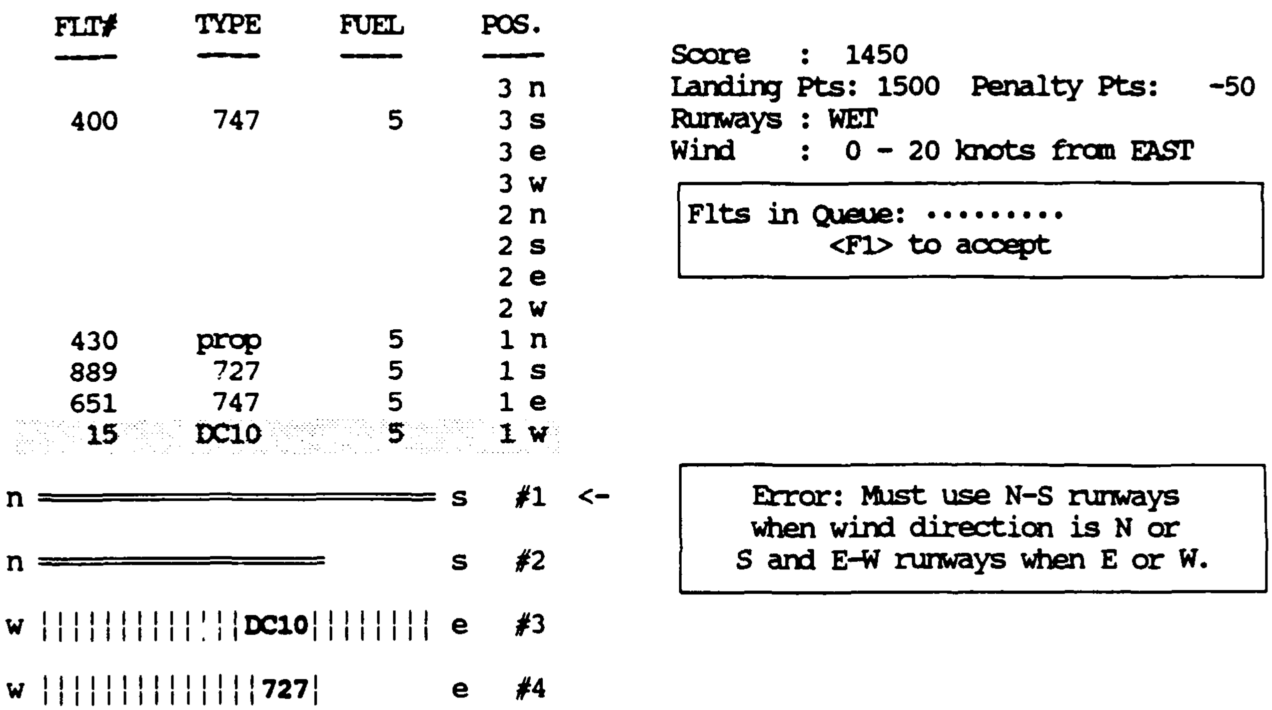

Figure A-3. ATC Task Screen with Error Feedback.

Table 1. Repeated-Measure ANOVA on Landings, Errors, and Keystrokes. Experiment 1.

		Dependent Variables					
		Landings		Errors		Keystrokes	
Factors	df	MS	F	MS	F	MS	F
Between-Subjects Factors							
Treatment	4	273.89	.37	2228.07	.75	2127421.23	1.84
Ability	1	71359.98	95.78***	112759.32	37.89***	52811308.08	45.56***
Treatment X Ability	4	176.30	.24	2012.95	.68	353557.77	.31
Error	547	745.06		2975.73		1159119.33	
Within-Subjects Factors							
Trials	8	56739.98	1807.63***	574.91	5.14***	24167745.37	873.73***
Treatment X Trials	32	13.28	.42	100.76	.90	60957.17	2.20***
Ability X Trials	8	660.28	21.04***	426.09	3.81***	168188.13	6.08***
Ability X Treatment X Trials	32	23.94	.76	188.27	1.68**	16892.92	.61
Error	4376	31.39		111.77		27660.45	

* $p < .05$
** $p < .01$
*** $p < .001$

Table 2. Repeated-Measure ANOVA on Minitrial RT, Accuracy, & Keystrokes. Experiment 2.

		Dependent Variables					
		Reaction Time		Accuracy		Keystrokes	
Factors	df	MS	F	MS	F	MS	F
Between-Subjects Factors							
Treatment	2	552.54	.07	4.22	.22	348.82	3.33*
Ability	1	552578.07	69.35***	1321.76	67.89***	933.35	8.90**
Treatment X Ability	2	8022.78	1.01	20.74	1.07	14.48	.14
Error	621	7968.08		19.47		104.86	
Within-Subjects Factors							
Trials	6	1975031.03	4363.37***	852.04	474.41***	3212.11	396.77***
Treatment X Trials	12	412.00	.91	1.45	.81	12.23	1.51
Ability X Trials	6	10437.74	23.06***	42.98	23.93***	5.45	.67
Ability X Treatment X Trials	12	385.84	.85	1.48	.83	9.32	1.15
Error	3726	452.64		1.80		8.10	

* $p < .05$
** $p < .01$
*** $p < .001$

Table 3. Repeated-Measure ANOVA on Landings, Errors, and Keystrokes. Experiment 2.

		Dependent Variables					
		Landings		Errors		Keystrokes	
Factors	df	MS	F	MS	F	MS	F
Between-Subjects Factors							
Treatment	2	216.78	.39	219.21	.17	921763.35	.81
Goal	1	65.84	.12	2308.56	1.76	319805.96	.28
Ability	1	13092.29	23.66***	10440.92	7.97**	33340937.18	29.29***
Treatment X Goal	2	677.56	1.22	606.90	.46	1331690.23	1.17
Treatment X Ability	2	95.75	.17	318.85	.24	757371.22	.67
Goal X Ability	1	48.88	.09	1091.75	.83	11525.04	.01
Treatment X Goal X Ability	2	59.66	.11	759.70	.58	406283.30	.36
Error	615	553.27		1310.15		1138242.25	
Within-Subjects Factors							
Trials	7	18623.95	1135.03***	1053.86	20.21***	11015901.59	521.30***
Trials X Treatment	14	16.45	1.00	31.07	.60	19533.48	.92
Trials X Goal	7	66.40	4.05***	32.18	.62	12245.17	.58
Trials X Ability	7	15.50	.94	195.20	3.74***	237314.38	11.23***
Trials X Treatment X Goal	14	16.24	.99	40.47	.78	8441.34	.40
Trials X Treatment X Ability	14	8.29	.51	93.49	1.79*	27074.87	1.28
Trials X Goal X Ability	7	21.04	1.28	45.23	.87	25553.74	1.21
Trials X Treatment X Goal X Ability	14	11.65	.71	65.18	1.25	18820.50	.89
Error	4305	16.41		52.15		21131.65	

* $p < .05$
** $p < .01$
*** $p < .001$

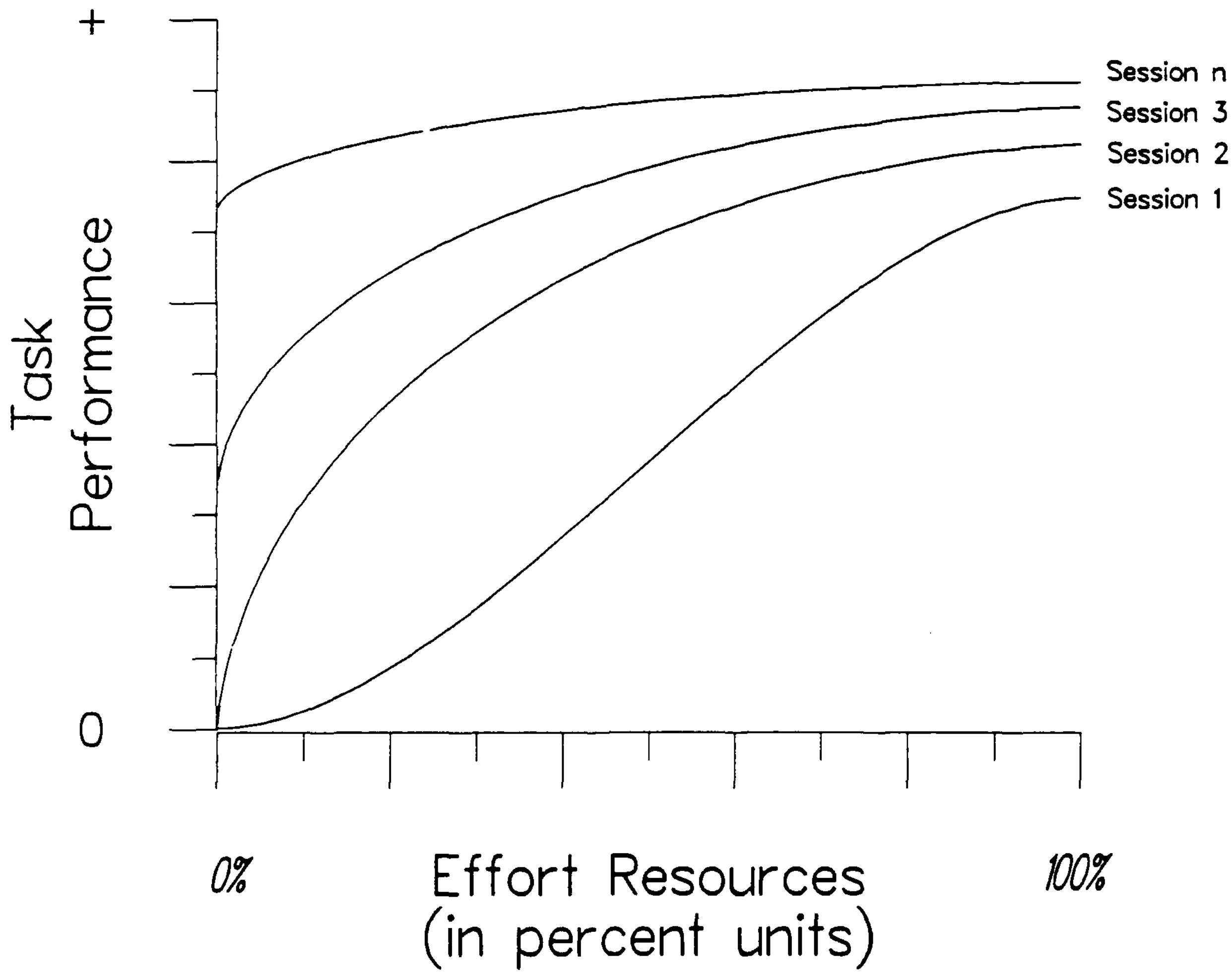

Figure 1. Changes in performance-resource functions as a result of sessions of practice. While the performance-resource function is initially resource-dependent (Session 1), as the number of practice sessions increases, the task becomes more resource-insensitive (as the skill becomes proceduralized).

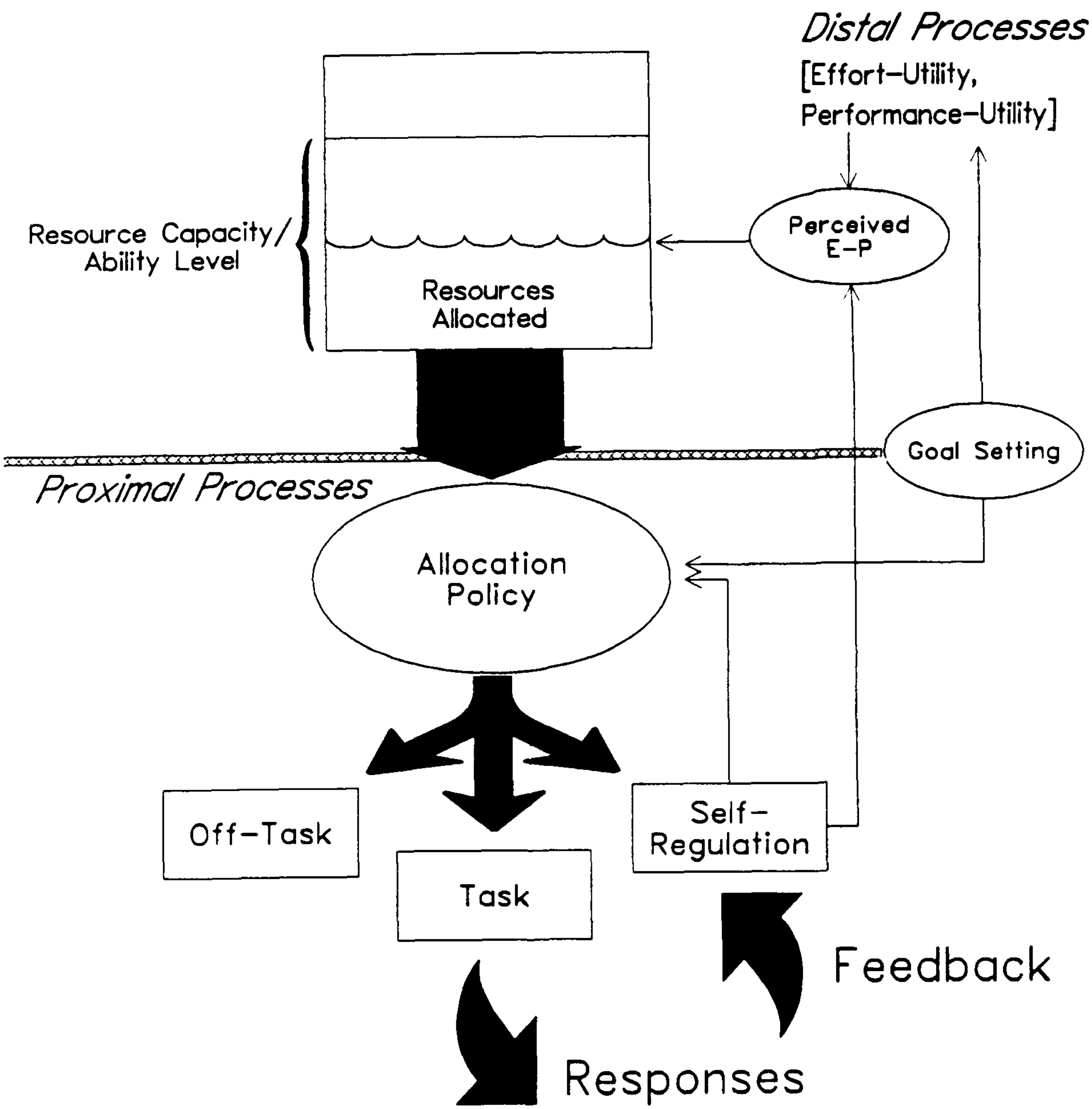

Figure 2. The Kanfer and Ackerman (1989) model of ability/motivation interactions for attentional effort. The model is derived from a model of attention proposed by Kahneman (1973).

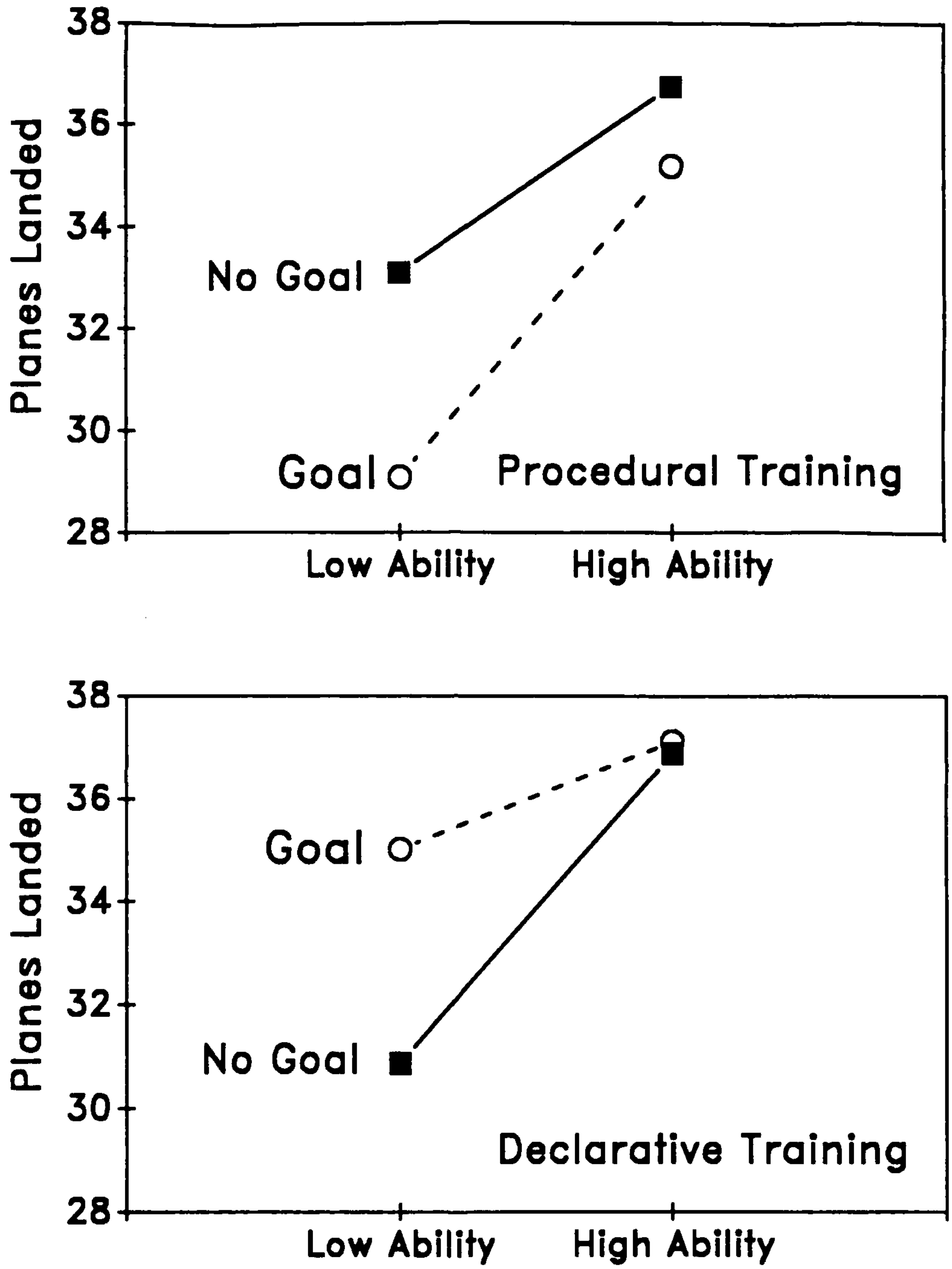

Figure 3. Planes landed -- Trial 6, by condition and by ability group (median split). Upper Panel: Procedural part-task training conditions; Lower Panel: Declarative part-task training conditions.

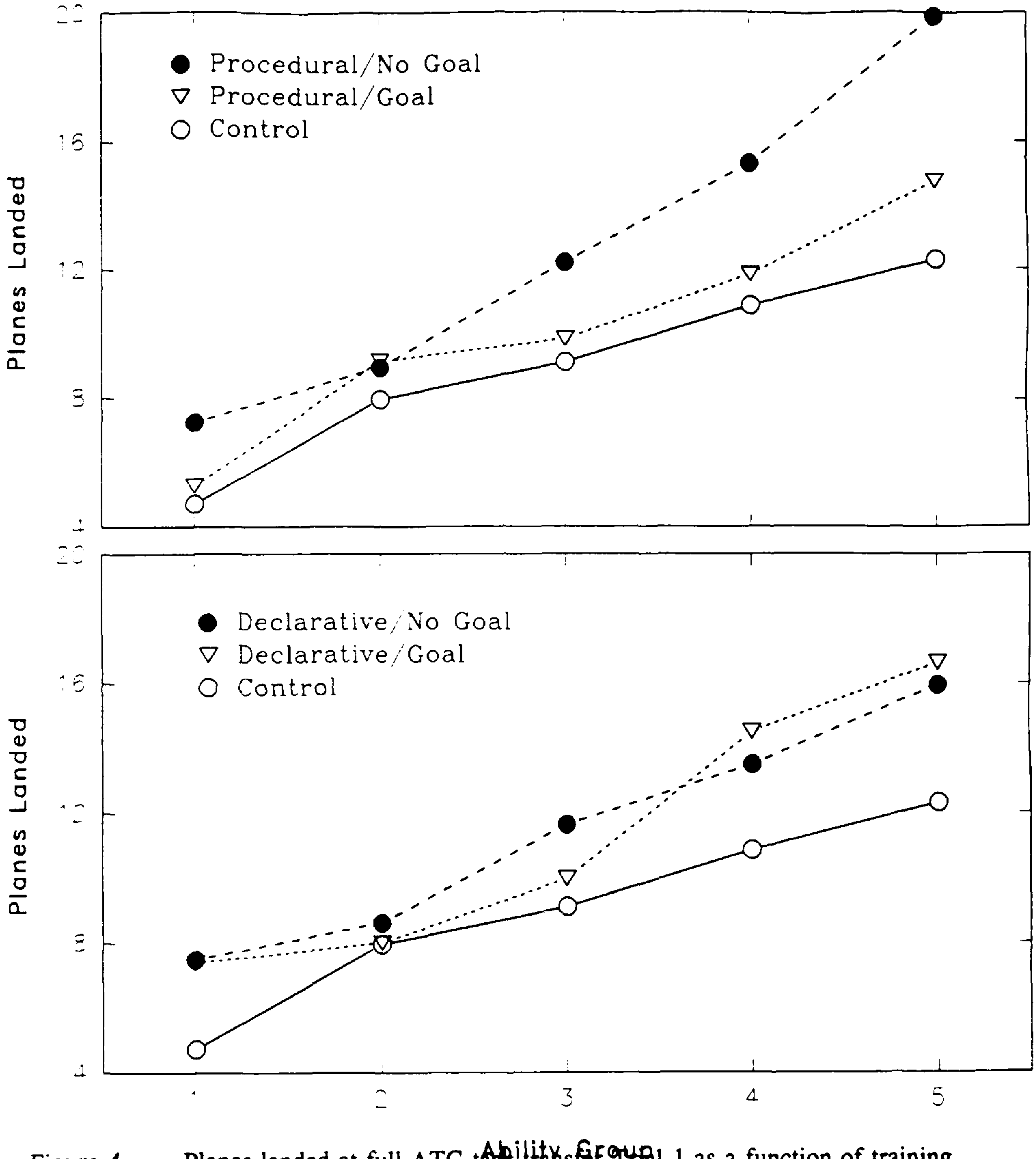

Figure 4. Planes landed at full ATC task transfer Trial 1 as a function of training condition, goal, and ability group (20*%ile* splits). Upper Panel: Procedural part-task training conditions; Lower Panel: Declarative part-task training conditions. Higher-ability is Ability Group #5, lower-ability group is #1. Control condition (no training - no-goal) is given in solid line and filled squares.

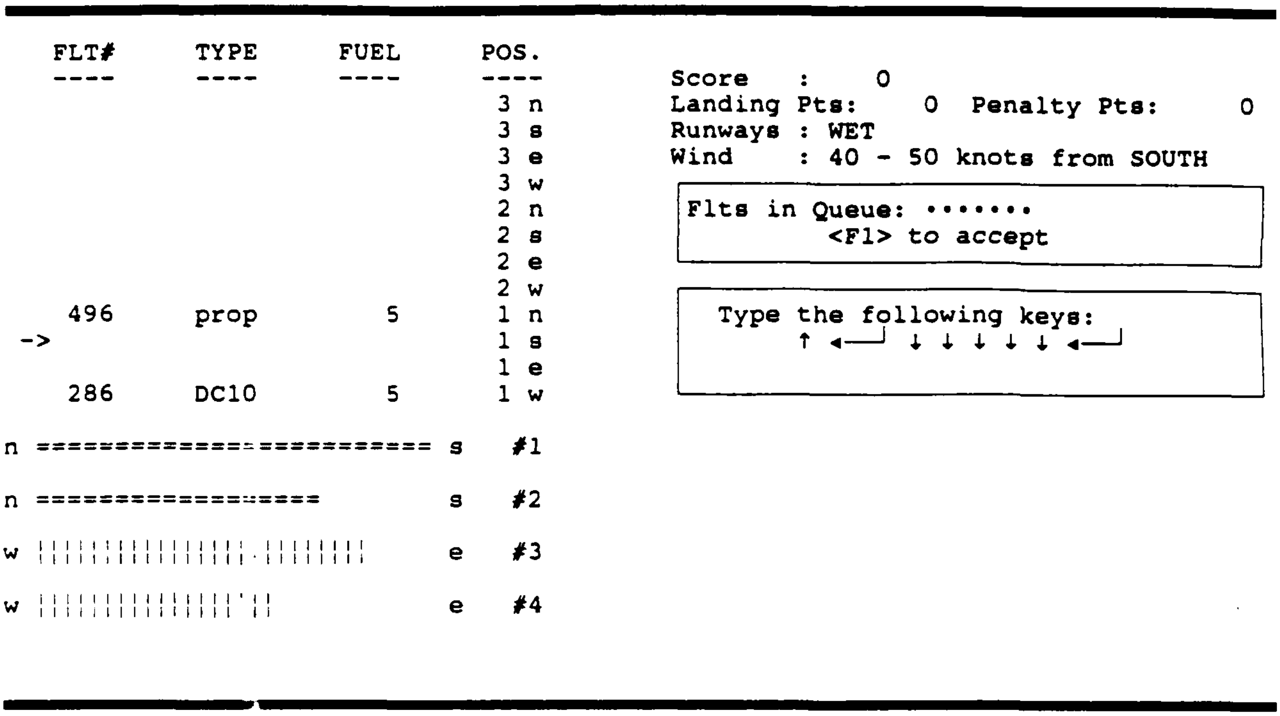

Figure 5. An illustration of a Procedural knowledge part-task training trial. The box in the middle right side of the figure shows the instructions to the subject.

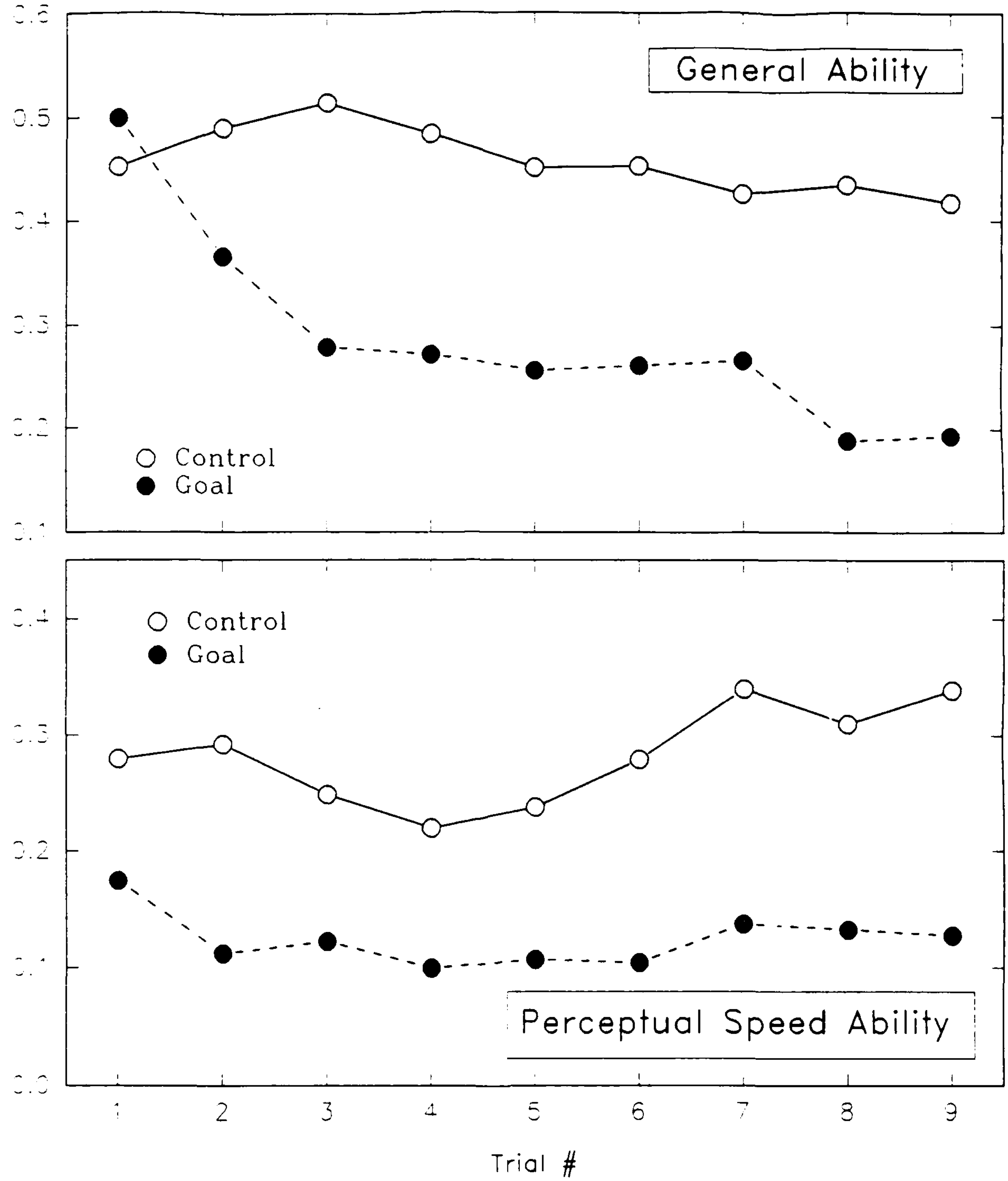

Figure 6. Ability-performance correlations for full ATC task transfer, Control and Goal conditions. Upper panel, General ability - Landings correlations. Lower Panel, Perceptual Speed ability - Landings correlations.

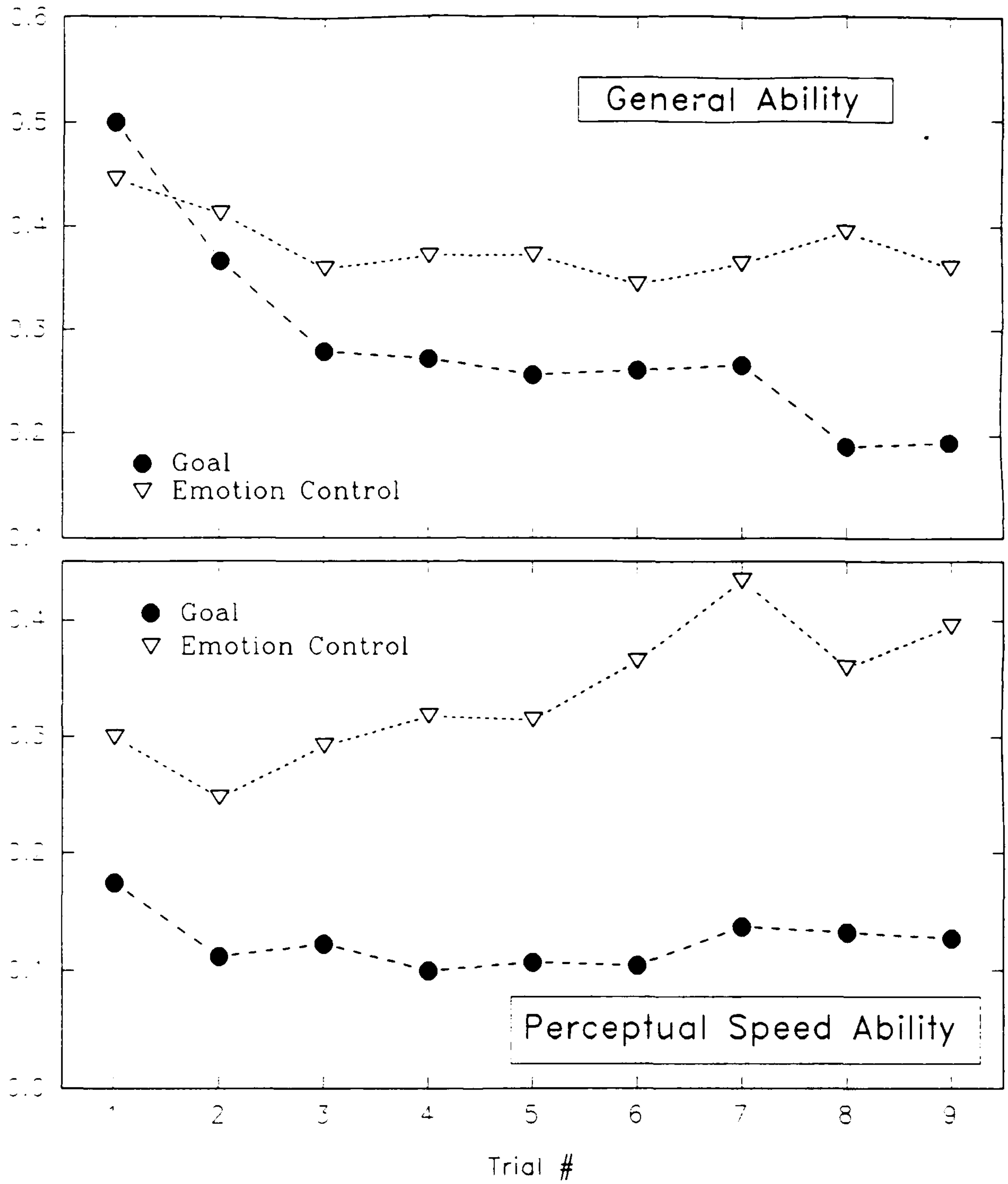

Figure 7. Ability-performance correlations for full ATC task transfer, Goal and Emotion Control conditions. Upper panel, General ability - Landings correlations. Lower Panel, Perceptual Speed ability - Landings correlations.

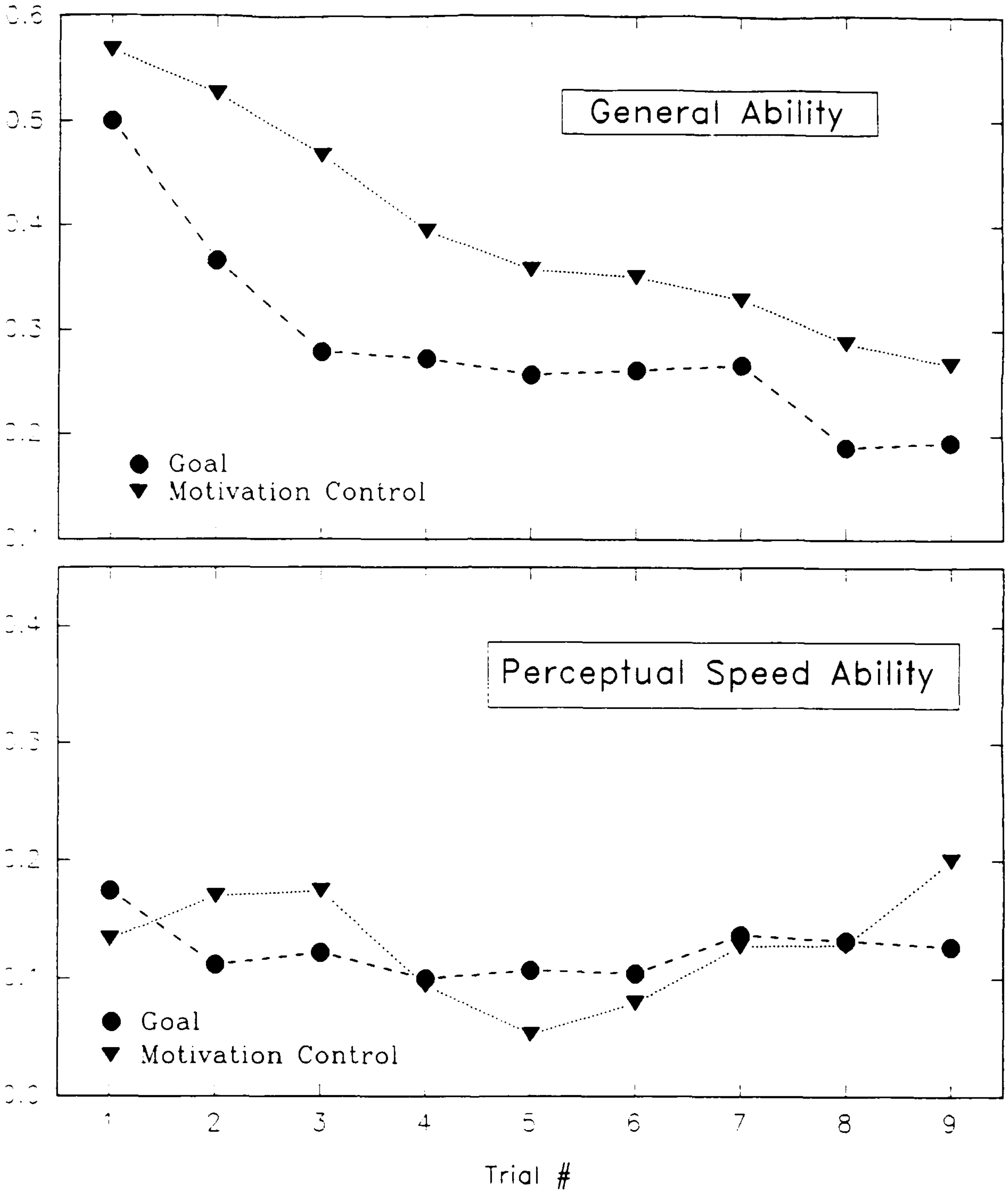

Figure 8. Ability-performance correlations for full ATC task transfer, Goal and Motivation Control conditions. Upper panel, General ability - Landings correlations. Lower Panel, Perceptual Speed ability - Landings correlations.

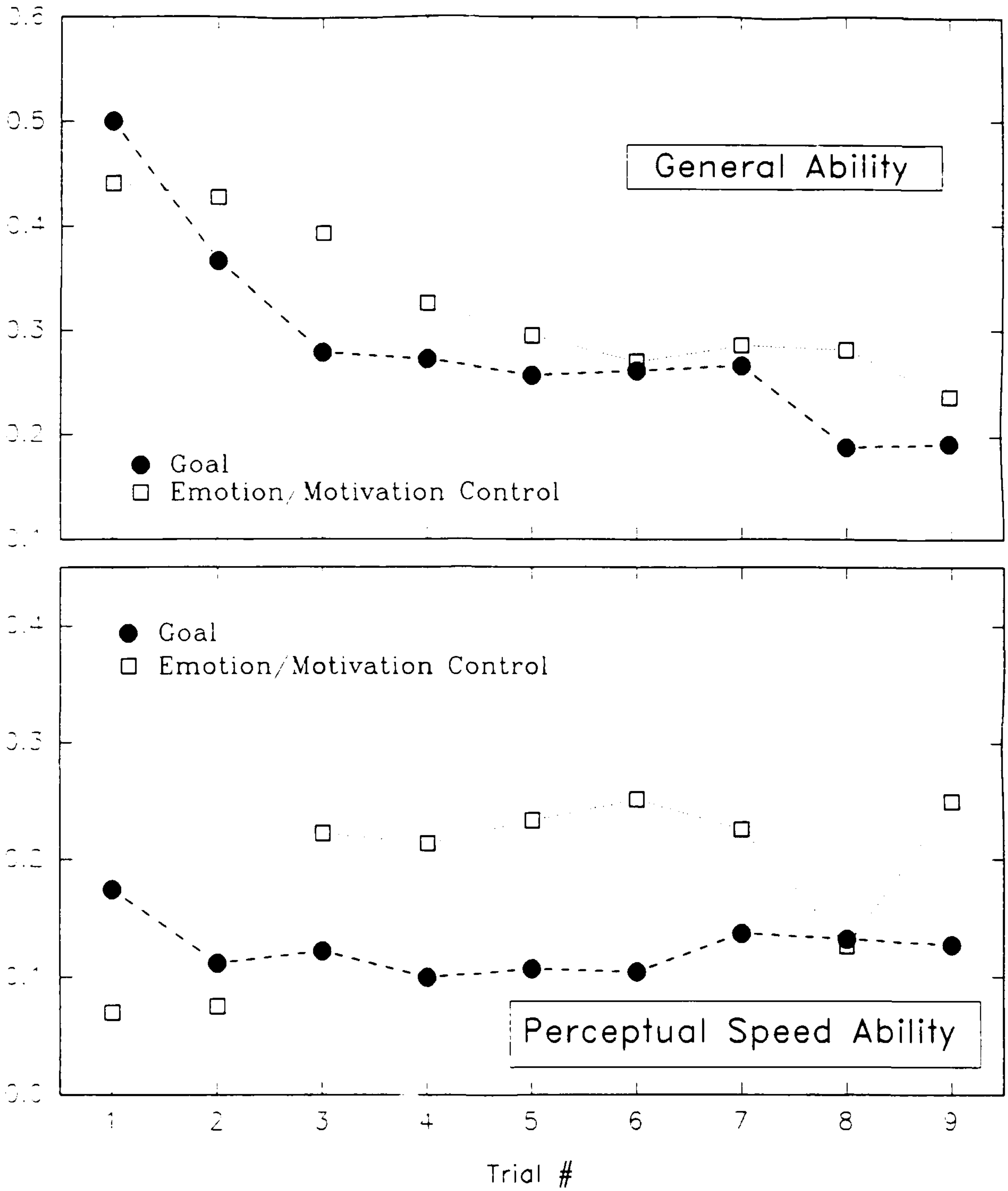

Figure 9. Ability-performance correlations for full ATC task transfer, Goal and Emotion/Motivation Control conditions. Upper panel, General ability - Landings correlations. Lower Panel, Perceptual Speed ability - Landings correlations.

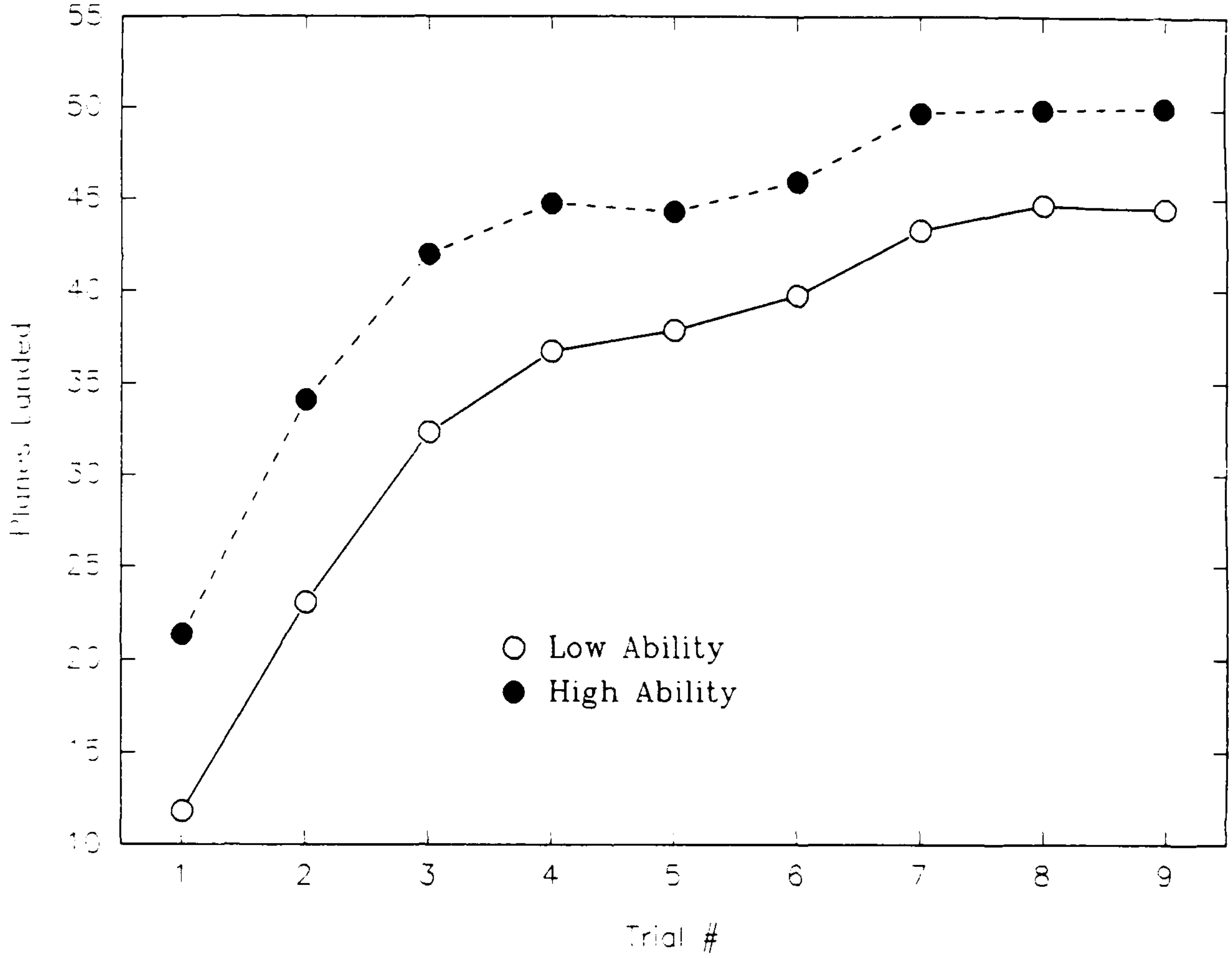

Figure 10. Planes Landed for full ATC task transfer and subsequent practice, for lower and Higher-ability subject groups.

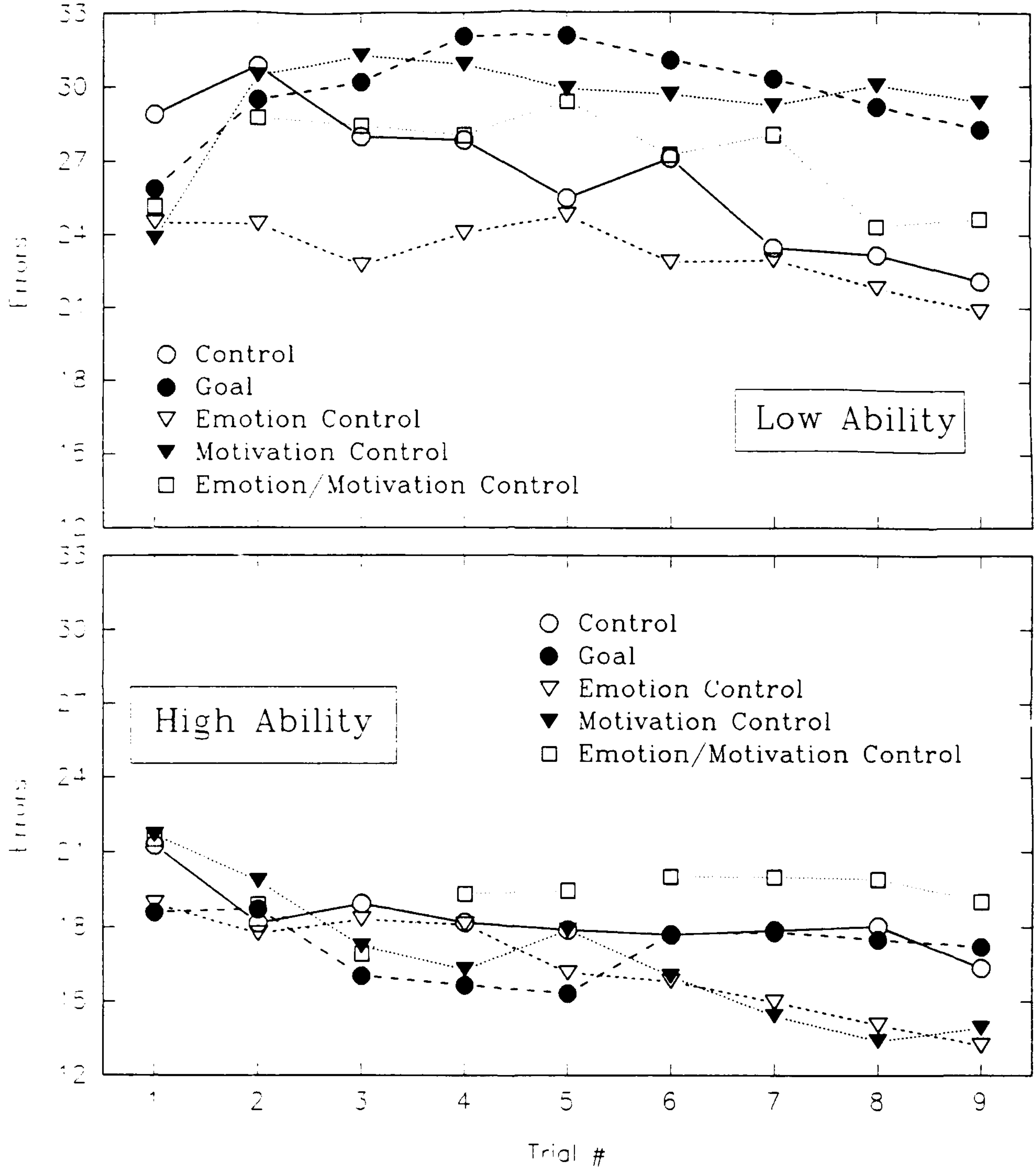

Figure 11. Errors for full ATC task transfer and subsequent practice, for lower and Higher-ability subject groups, by treatment condition.

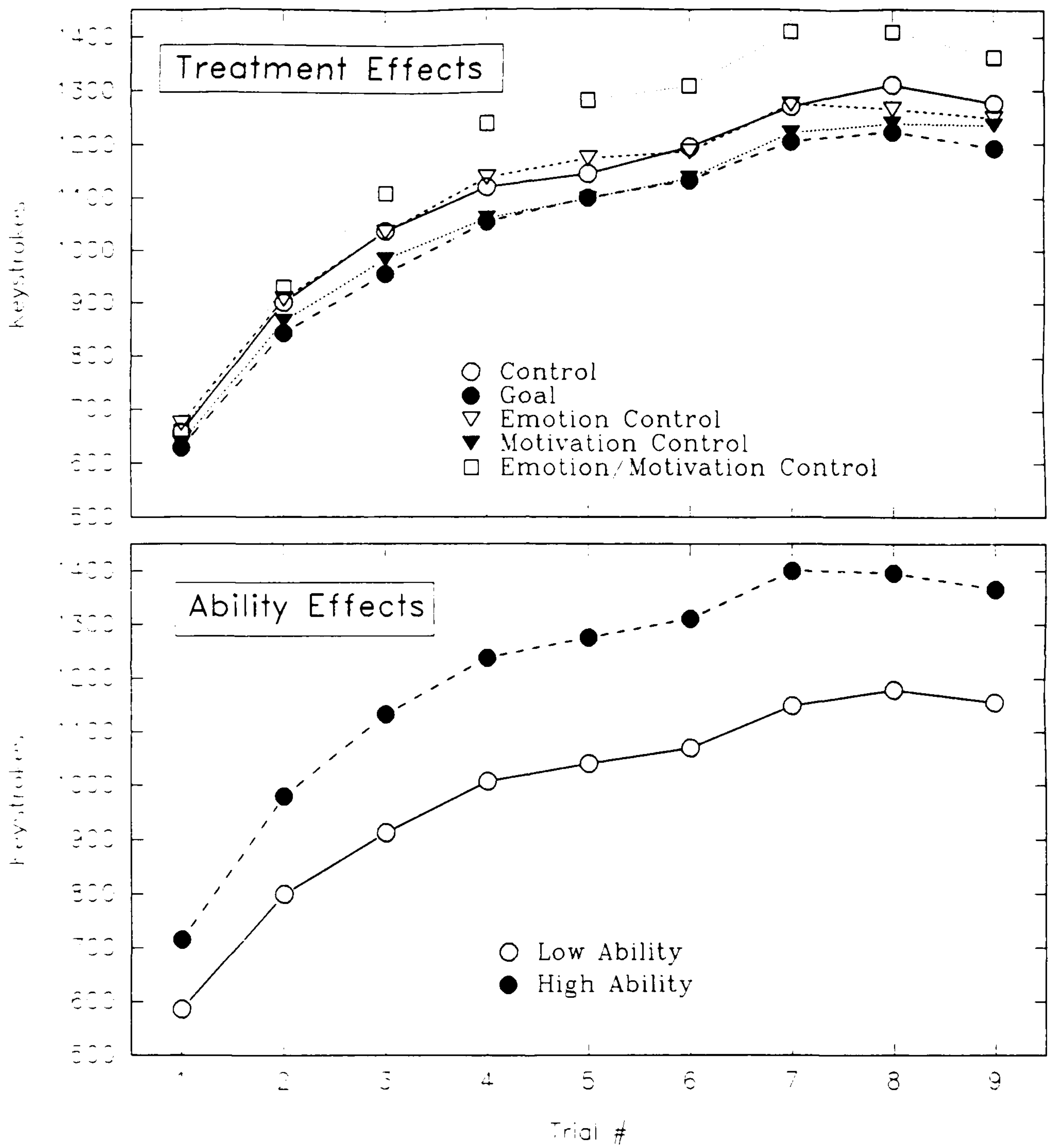

Figure 12. Keystrokes for full ATC task transfer and subsequent practice. Upper panel: for all five treatment conditions. Lower Panel, for lower and higher-ability subject groups.

```
   FLT#      TYPE      FUEL      POS.
   ----      ----      ----      ----       Score      :     0
    396      DC10         6       3 n       Landing Pts:     0  Penalty Pts:     0
                                  3 s       Runways : WET
     85      prop         6       3 e       Wind      :   0 - 20 knots from NORTH
    477      DC10         6       3 w
    902       747         6       2 n       Flts in Queue: ••••••
    295      DC10         6       2 s               <F1> to accept
    796       747         5       2 e
                                  2 w
                                  1 n        Land plane in 1w (Flt #299)
                                  1 s          onto Runway #2.  Land plane
    194      DC1C         6       1 e          in 1e (Flt #194) onto Runway #1.
 -> 299      prop         6       1 w

n =========================  s    #1

n ==================         s    #2

w ||||||||||||||||||||||||||  e    #3

w ||||||||||||||||||          e    #4
```

Figure 13. An illustration of a part-task training minitrial. The box in the middle right side of the figure shows the instructions to the subject.

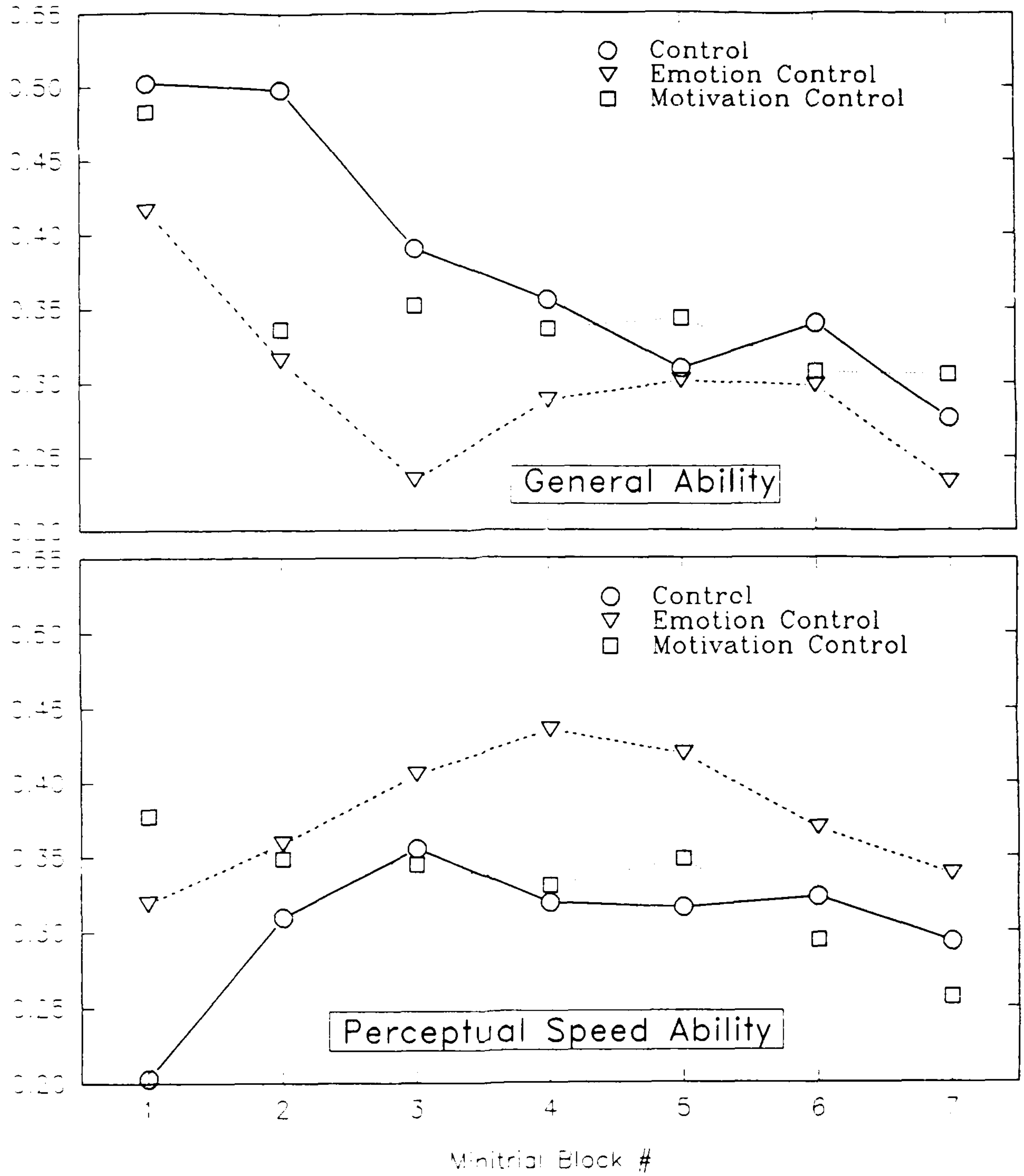

Figure 14. Ability-performance correlations for minitrial reaction time performance, by treatment condition. Upper panel, General ability - minitrial RT correlations. Lower Panel, Perceptual Speed ability - minitrial RT correlations.

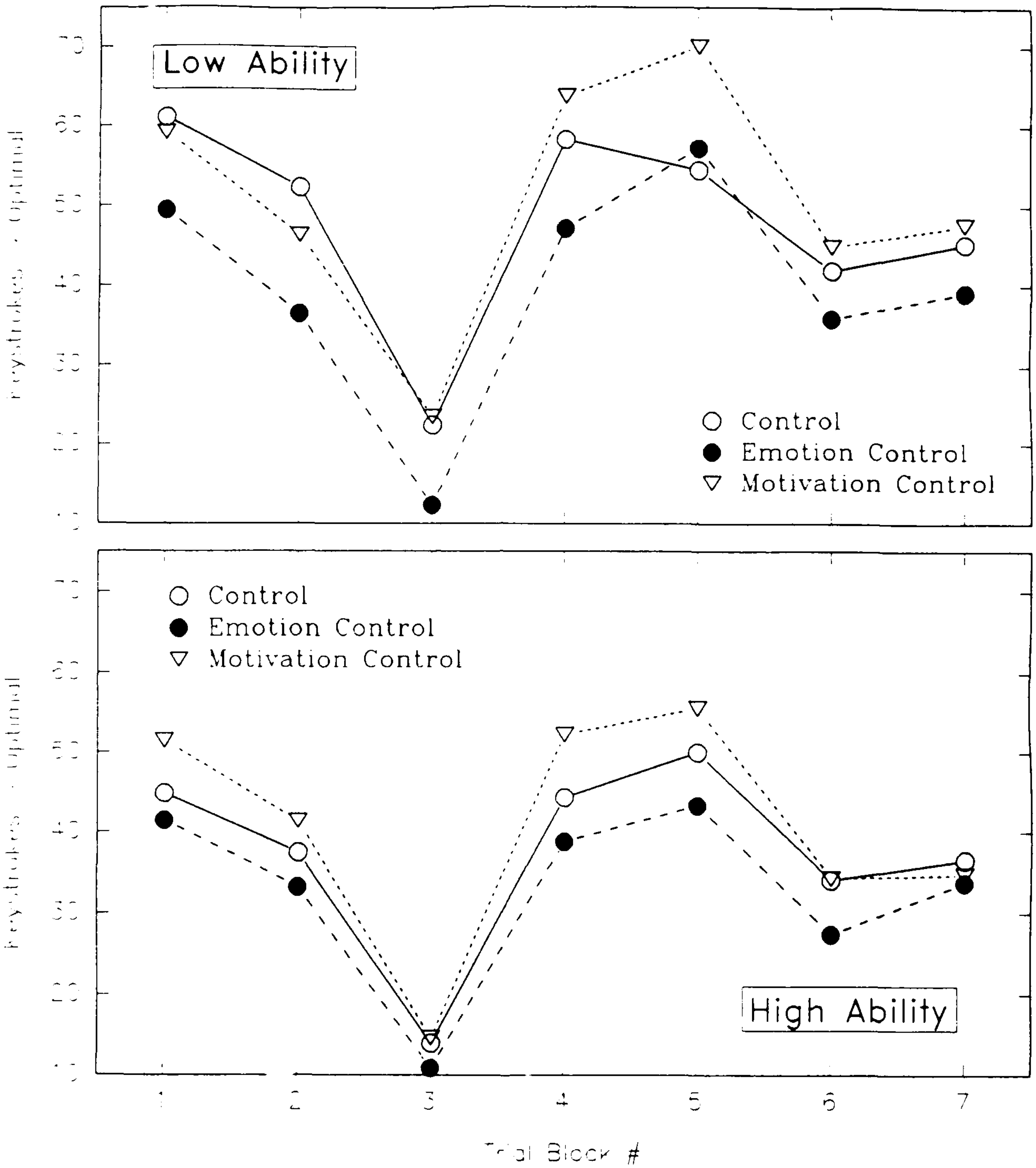

Figure 15. Keystrokes for minitrial practice trial blocks, by treatment condition. Upper panel: Lower-ability subjects. Lower Panel, Higher-ability subjects.

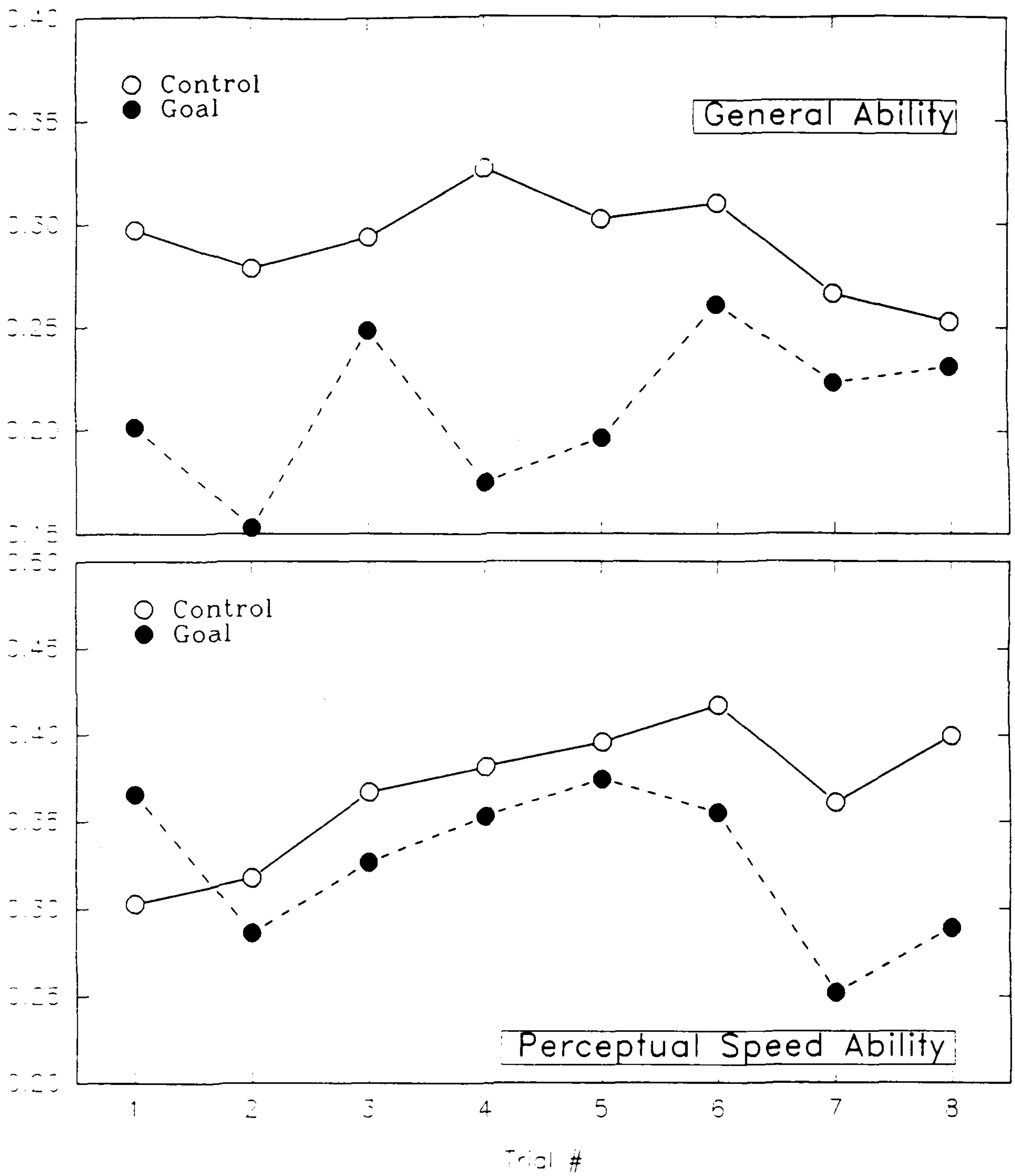

Figure 16. Ability-performance correlations for full ATC task transfer, Control and Goal conditions. Upper panel, General ability - Landings correlations. Lower Panel, Perceptual Speed ability - Landings correlations.

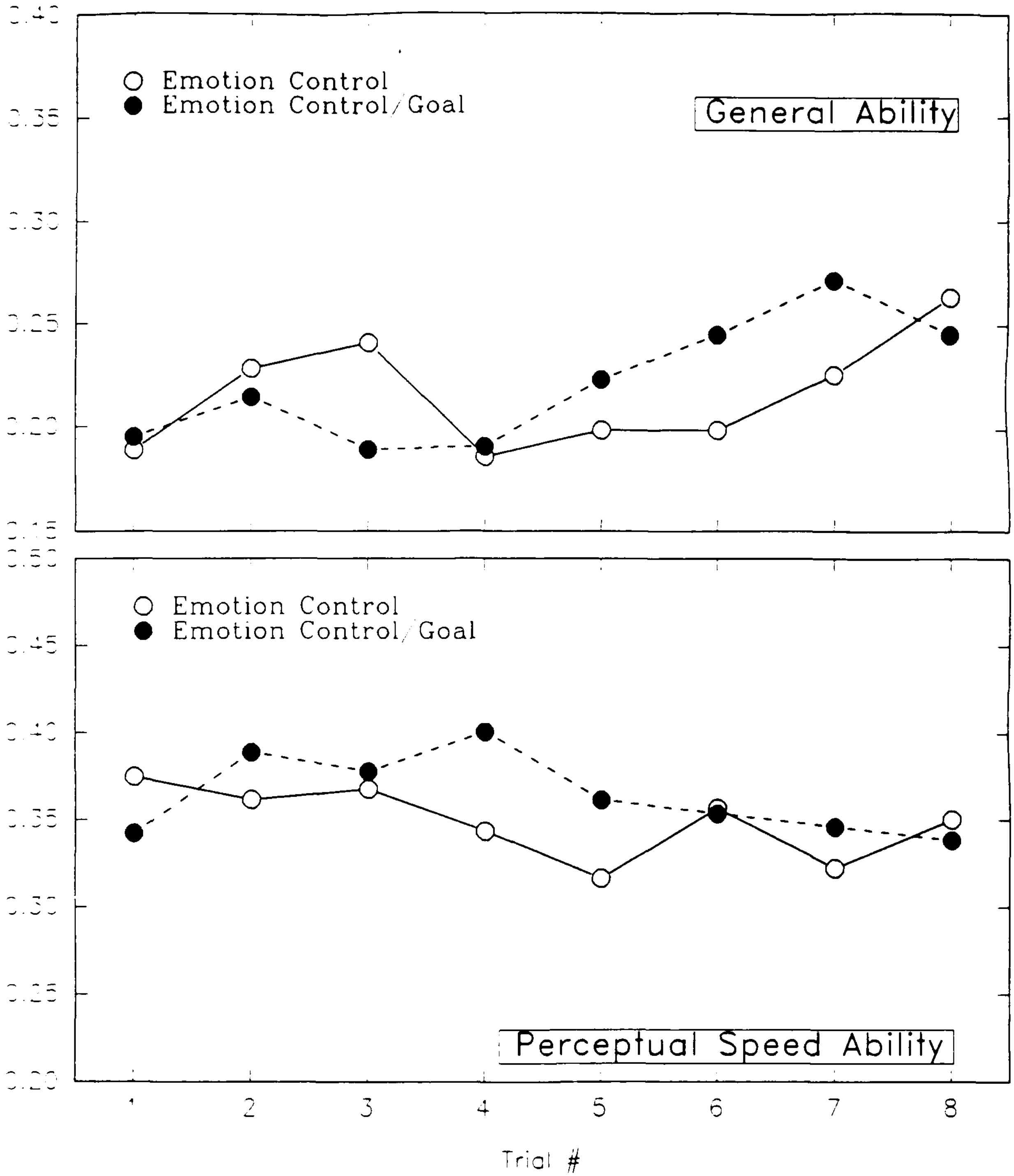

Figure 17. Ability-performance correlations for full ATC task transfer, Emotion Control and Emotion Control/Goal conditions. Upper panel, General ability - Landings correlations. Lower Panel, Perceptual Speed ability - Landings correlations.

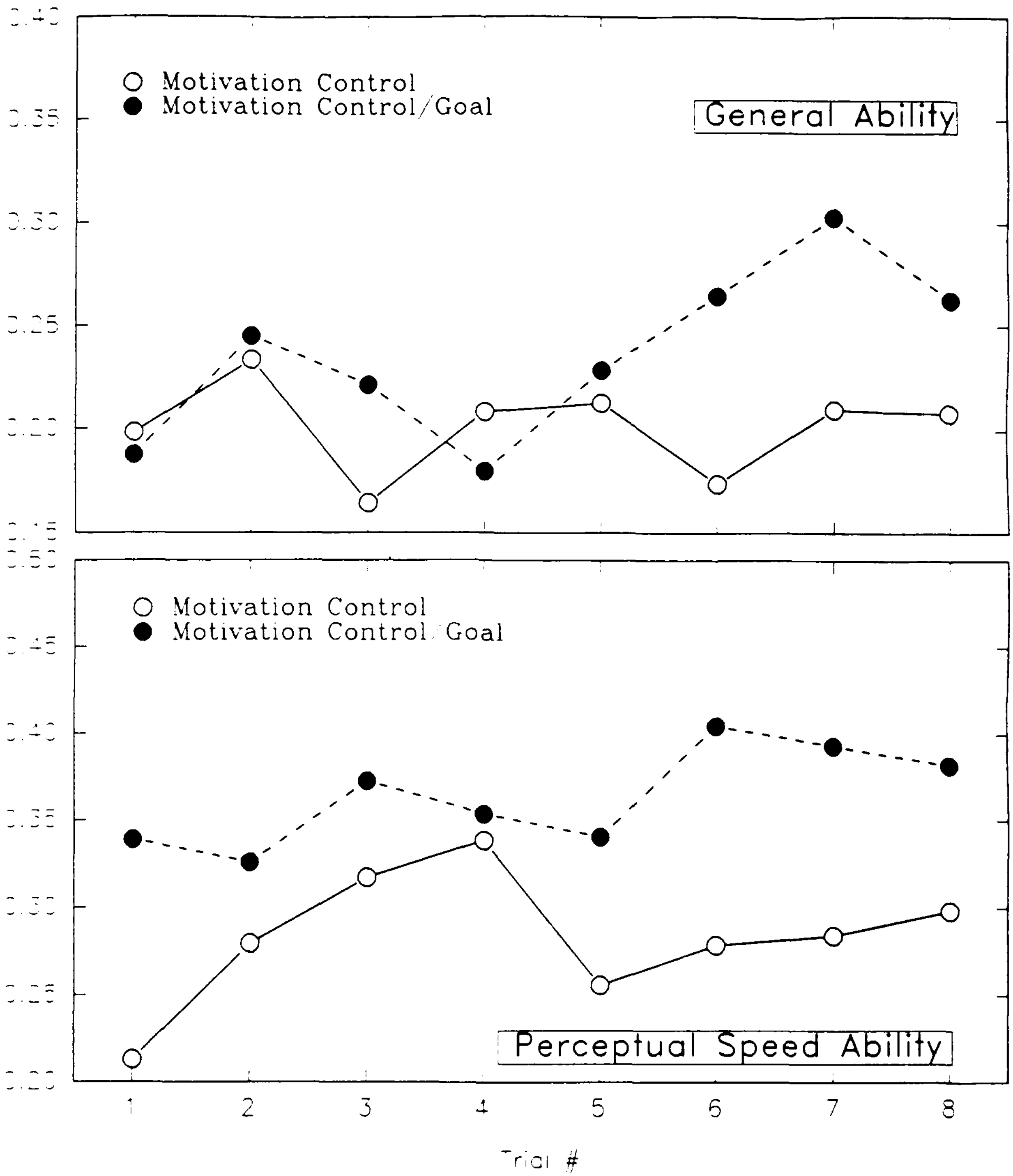

Figure 18. Ability-performance correlations for full ATC task transfer, Motivation Control and Motivation Control/Goal conditions. Upper panel, General ability - Landings correlations. Lower Panel, Perceptual Speed ability - Landings correlations.

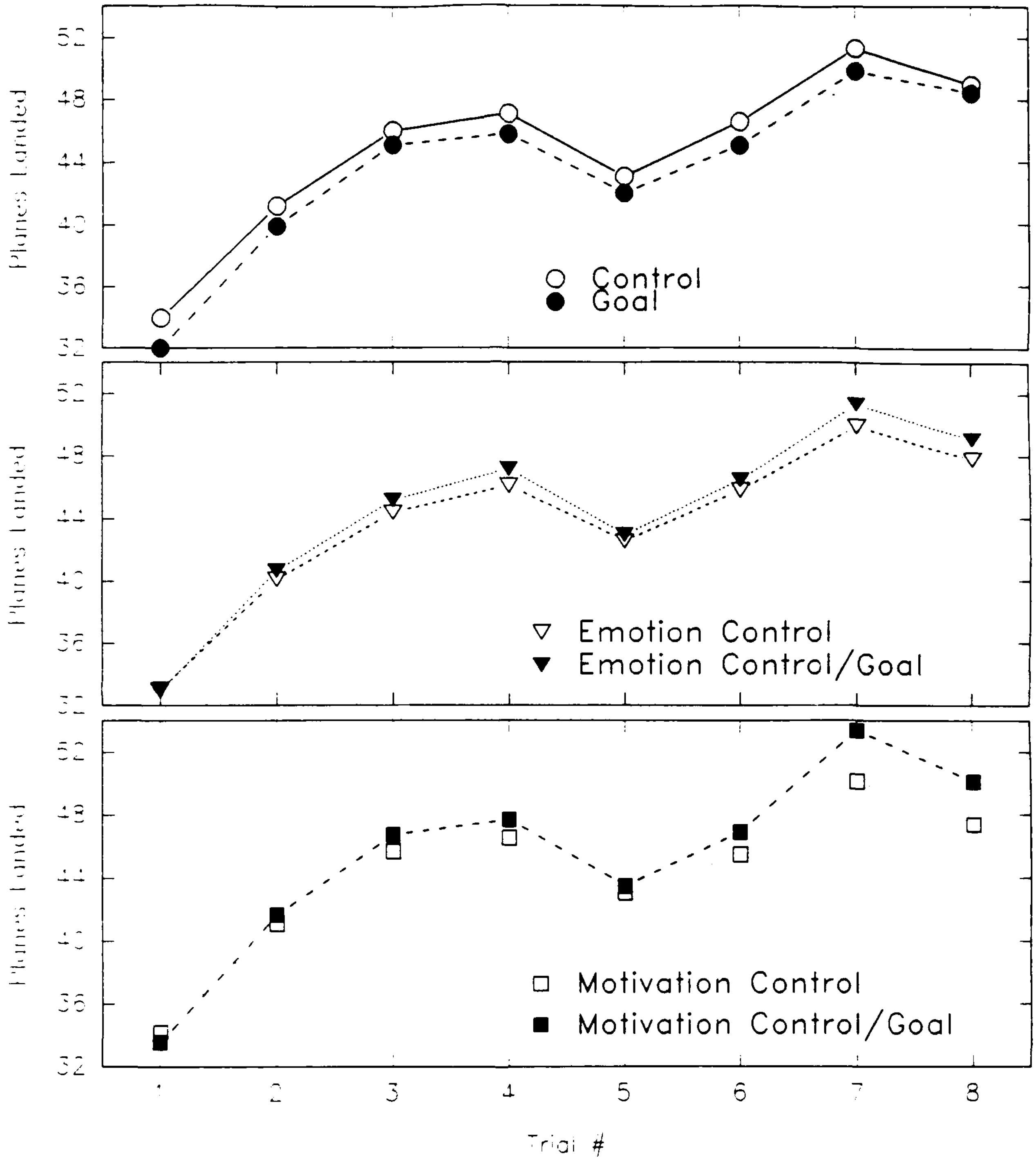

Figure 19. Planes Landed for full ATC task transfer and subsequent practice, by minitrial treatment and transfer-based goal procedure. Upper Panel: Control vs. Goal condition; Middle Panel: Emotion Control vs. Emotion Control/Goal condition; Lower Panel: Motivation Control vs. Motivation Control/Goal condition.

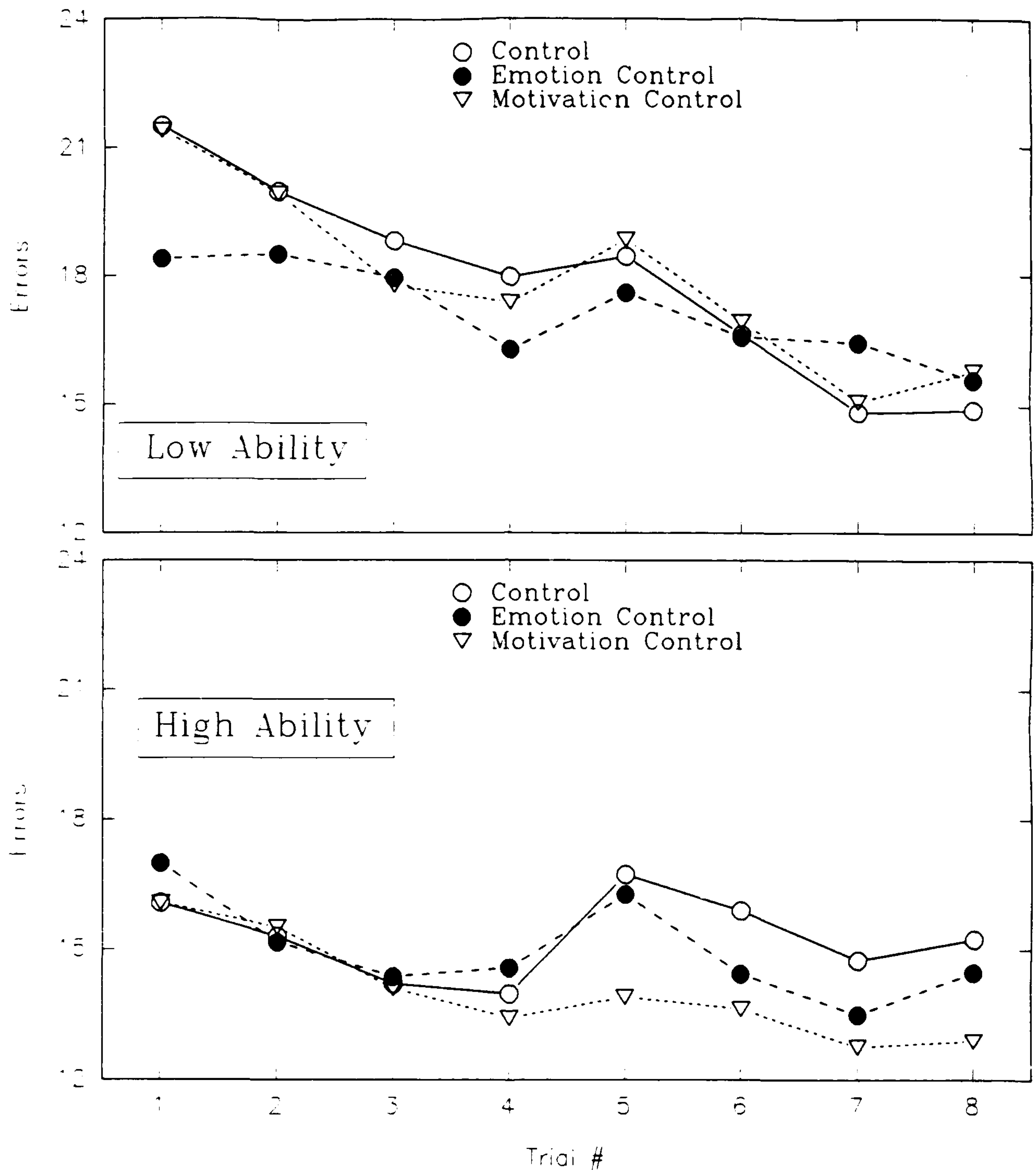

Figure 20. Errors for full ATC task transfer and subsequent practice bv treatment condition. Upper Panel: Lower-ability subjects; Lower Panel: Higher-ability subjects.

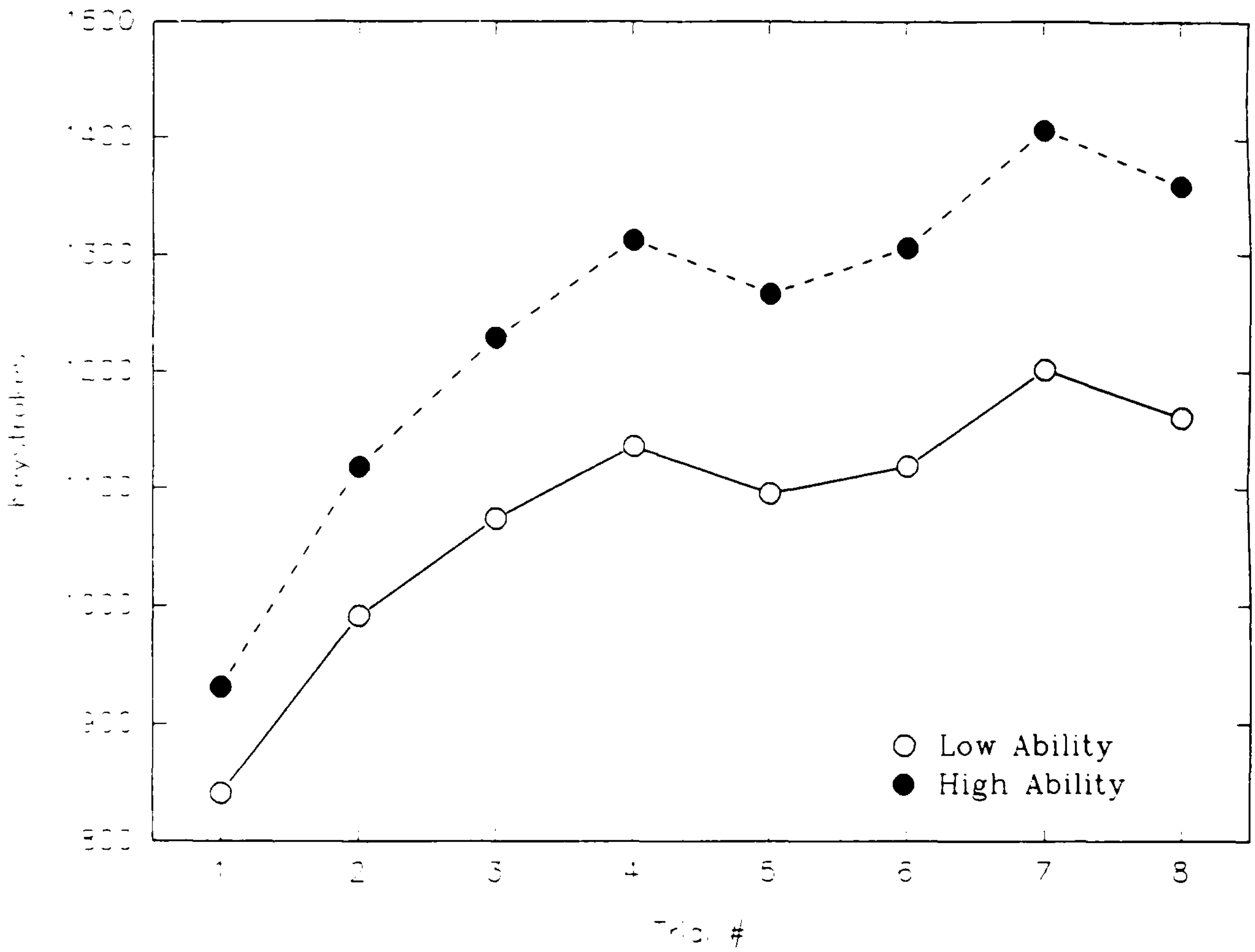

Figure 21. Keystrokes for ATC task transfer and subsequent practice by ability level.