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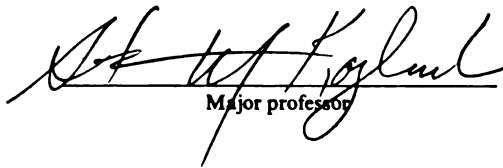
AN EXAMINATION OF THE INSTRUCTIONAL, MOTIVATIONAL,
AND EMOTIONAL ELEMENTS OF ERROR TRAINING

presented by

Bradford S. Bell

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Psychology


Major professor

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**AN EXAMINATION OF THE INSTRUCTIONAL, MOTIVATIONAL, AND
EMOTIONAL ELEMENTS OF ERROR TRAINING**

VOLUME I

By

Bradford S. Bell

A DISSERTATION

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ABSTRACT

AN EXAMINATION OF THE INSTRUCTIONAL, MOTIVATIONAL, AND EMOTIONAL ELEMENTS OF ERROR TRAINING

By

Bradford S. Bell

Changes in the nature of work and organizations have called many traditional training techniques and principles into question. As a result, several new approaches to training have been developed to promote active learning and develop adaptive expertise (Smith, Ford, & Kozlowski, 1997). One popular active learning strategy is error training. In contrast to traditional training approaches, error training promotes active, exploratory learning, encourages errors during training, and helps trainees to monitor and control their negative emotions.

Although research conducted over the last decade has shown that error training can enhance learning and retention and promote the development of generalizable skills (Ivancic & Hesketh, 1995/1996), our understanding of error training has been limited by the fact that past research has (1) confounded the key elements that distinguish error training from traditional training approaches, and (2) has not examined the mechanisms by which error training may impact learning and performance. As a result, it is difficult to determine which elements are critical to the success of error training and to identify the mechanisms by which these elements operate. The present study, therefore, was designed to tease apart the instructional, motivational, and emotional components of error training and determine their independent and interactive effects on relevant training variables. In addition, the current study investigated numerous mechanisms by which

error training is thought to have its effects and explored the role of individual differences in error training.

Three hundred fifty undergraduate college students were trained to operate a complex radar control simulation during a three-hour training session. Results showed that the instructional and motivational elements of error training positively influenced participants' knowledge and performance. The effects on performance were greatest for far transfer, which provides further evidence that active learning techniques are best suited for developing generalizable skills. In addition, all three elements were shown to influence a number of the instructional, motivational, and emotional mechanisms. Finally, the individual differences measured in the current study exhibited significant relationships with the training processes and the effectiveness of the error training elements depended, in part, on the cognitive ability and dispositional traits of trainees.

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INTRODUCTION

Over the years, much of training research has focused on the learner as a passive recipient, rather than as an active participant, to various interventions or designs (Ford & Kraiger, 1995). This passive orientation is partially the product of attempts to eliminate errors from training. Skinner (1953, 1968) and other behaviorists argued that errors should be eliminated from training because they act as aversive stimuli that reduce motivation and facilitate the adoption of erroneous habits. Similarly, humanistic tradition argues that errors are detrimental because they cause stress, anxiety, and frustration, which in turn impede learning and performance. As a result, classic approaches to training have been characterized by tightly structured training programs that guide individuals step-by-step through the learning process and explicitly instruct individuals on the complete task and its concepts, rules, and strategies (Smith, Ford, & Kozlowski, 1997). This proceduralized or programmed instruction is designed to maximize the chances of success and minimize the number of errors committed.

Although proceduralized, errorless learning has historically dominated training research and practice, recent changes in the nature of work have called this approach into question. Technological advances have created jobs that are more cognitively complex and demanding (Smith et al., 1997; Tannenbaum & Yukl, 1992). More importantly, today's complex and dynamic tasks often require individuals to develop skills that can be generalized to ill structured and novel problems (Smith et al., 1997). Research suggests that while proceduralized instruction is sometimes beneficial for near transfer (reproducible skills), it may impede the development of generalizable skills (e.g.,

Carlson, Lundy, & Schneider, 1992; McKendree & Carroll, 1987). In addition, proceduralized instruction and other traditional training approaches assume that work environments are largely predictable and that training designs can be identified to prepare trainees to respond appropriately across routine job situations (Smith et al., 1997). As tasks become more complex and dynamic, however, it becomes increasingly more difficult to develop tutorial expositions of the knowledge domain (Beishuizen, 1992). Furthermore, advanced technologies have created opportunities for distributed training and, therefore, a greater number of individuals are participating in training without the step-by-step guidance of an instructor or trainer. All of these factors raise questions about both the practicality and effectiveness of using proceduralized instruction to meet current training needs.

Due to the limitations associated with proceduralized, errorless training in today's training environments, the training literature has recently begun to examine the impact of increasing the level of participation of individuals in their own training. This active approach to training is exemplified by a new breed of instructional strategies designed to promote active learning. These active learning strategies attempt to not only engage individuals' metacognitive and self-regulatory processes by putting them more in control of their learning but also facilitate an inductive learning process in which individuals must explore and experiment with the task to infer and learn the rules, principles, and strategies for effective performance (Smith et al., 1997). Interest in these new techniques has grown as research has shown that they often lead to increased learning and performance and more effective transfer of skills (e.g., Frese et al., 1988; Kamouri, Kamouri, & Smith, 1986; McDaniel & Schlager, 1990). In addition, effective training

that involves giving control to learners offers practical benefits in today's distributed and computerized training environments (Steinberg, 1977, 1989; Williams, 1993).

One of the more popular active learning strategies is error training. In contrast to the more traditional approach to training, error training is based on the idea that errors are a normal and valuable part of the learning process (Frese 1991, 1995). In error training, individuals are not only encouraged to actively explore and experiment with the task but are also told to make errors and learn from their mistakes. Proponents of error training have offered numerous arguments for why errors should be allowed, rather than eliminated, in training. For example, it has been argued that errors highlight potential pitfalls and error-prone problem areas, which in turn increases understanding of a system and facilitates the development of more accurate and complete mental models (Frese, 1995; Ivancic & Hesketh, 1995/1996). Also, errors are inevitable in most work situations, so many researchers have argued that individuals should learn how to deal with negative information about their performance and correct their mistakes (Frese et al., 1991; Gully, Payne, Kiechel, & Whiteman, in press).

Error training has been studied now for over a decade. In that time, research has generally provided support for the concept. Numerous studies have compared error training to more traditional training approaches and have shown that including errors in training can aid in learning and retention and facilitate the development of generalizable skills (e.g., Frese, 1991; Frese & Altmann, 1989; Frese et al., 1991; Ivancic & Hesketh, 2000; Nordstrom, Wendlend, & Williams, 1998). Although this research suggests that error training may be a useful tool in meeting today's training challenges, a fundamental

question remains largely unanswered – what explains the apparent effectiveness of error training?

Although past theoretical and empirical work on error training has placed considerable emphasis on the importance of errors in the learning process, recent research suggests that the act of simply making errors has limited instructional potential. Frese (2002), for example, compiled results from a number of his studies on error training and found that the correlation between errors and learning and performance was negative (approximate $r = -.11$). In addition, Ivancic and Hesketh (in press) recently found that exposing individuals to errors committed by others did not result in improved performance. The point is not to suggest that errors cannot facilitate learning, because research has shown that they can. However, there is growing evidence that the benefits of error training and other active learning strategies may not arise from simply making errors, but rather from how individuals use errors in the learning process, how individuals react to errors during learning, and other aspects of the active approach to learning, such as increased exploration, enhanced metacognitive and self-regulatory skills, and the activation of a learning rather than a performance orientation.

It is important, therefore, to move away from the dominant focus on errors and take a more comprehensive approach that examines how the different training design features associated with error training contribute to improved training effectiveness. However, it is difficult to address the issue of what underlies the effectiveness of error training because past research has typically confounded the key elements that distinguish error training from more traditional training approaches. Although error training combines multiple training elements that are each designed to promote active learning,

past research has typically operationalized error training as a unidimensional strategy. These elements, which I view as primarily instructional, motivational, and emotional in nature, are:

- (1) Instructional – Error training provides an unstructured, or exploratory, learning environment and encourages trainees to experiment with the task; traditional training techniques involve tightly structured, proceduralized instruction that prevents or minimizes exploration.
- (2) Motivational – Error training encourages trainees to make errors and learn from their mistakes; traditional training techniques encourage error avoidance and tell trainees that errors are not part of learning.
- (3) Emotional – Error training incorporates emotion-control statements designed to alleviate the stress, anxiety, and frustration that often surround errors; traditional training typically does not involve emotional control strategies.

While theoretical work has recognized these three components of error training, empirical research has typically combined them into a single error training strategy. As a result, it is difficult to determine which element(s) of error training account for the positive findings. It may be that only one of these components is really having an impact, or it could be that all three elements are important and contribute to the creation of a more active learning environment; currently we do not know. One goal of the present study, therefore, was to tease apart these instructional, motivational, and emotional components of error training to determine their independent and interactive effects on relevant training variables.

A second and related limitation stems from the fact that past research provides little indication of how error training has its effects. Although theoretical work suggests numerous instructional, motivational, and affective mechanisms by which error training may impact learning and performance, empirical research has been limited in its focus on potential process variables. Some work by Dormann and Frese (1994) suggests that increased exploration partially explains the positive effects of error training, and Nordstrom et al. (1998) found that error training enhanced intrinsic motivation. However, even the contributions of these studies are limited because it is difficult to know which elements of error training are producing these effects. A second goal of the present study, therefore, was to provide a detailed examination of the paths by which error training impacts learning and performance. The current study used research not only on error training but also in related areas such as exploratory learning and emotional control strategies to identify mechanisms that might explain how each of the components of error training has its effects. A conceptual model was developed and tested that specifies relationships between the three components of error training, relevant process variables, and multiple training outcomes.

A final goal of the current study was to examine several factors that may moderate the effects of error training on important training processes and outcomes. One such factor is task complexity. While research has shown that error training produces fairly positive results on stable, procedural tasks, what is less well known is whether error training is equally as effective for training more complex and dynamic skills (Wood, Kakebeeke, Debowski, & Frese, 2000). A number of individual differences may also determine the relative effectiveness of error training. For example, a recent study by

Gully and colleagues (2002) found that “make errors” instructions were beneficial for individuals with high levels of openness to experience, but detrimental for individuals high in conscientiousness. A number of researchers have also suggested that because exploration and recovering from errors requires cognitive resources (e.g., attention), error training may be more appropriate for high ability individuals (Gully et al., 2002; Ivancic & Hesketh, 1995/1996). Thus, the current study examined the impact of skill complexity and several individual difference variables on the instructional, motivational, and emotional effects of error training.

Overall, our understanding of error training and the mechanisms that explain its effects has not advanced much since Frese and colleagues (1991) observed, “We do not know whether strategy, memory, motivational, or emotional effects are important or whether all of them have an influence” (p. 91). The central goal of the current study, therefore, was to provide a detailed and comprehensive examination of the instructional, motivational, and emotional effects of error training. In many ways, however, error training is representative of a number of active learning techniques, such as exploratory learning and mastery training. Thus, at a broader level, this study also contributes to a better understanding of the basic components of effective active learning techniques and the means by which they exert effects. Future research and practice may be able to utilize this knowledge in the development of additional learning tools and techniques that make use of active learning principles.

In the literature review that follows, I begin by providing a brief overview of active learning. I discuss the shift of training from a more passive to a more active approach and describe the primary features of active learning strategies. I then focus

attention specifically on error training. I first provide an overview of the literature on errors and error detection and review several error taxonomies, such as those developed by Reason (1990) and Rasmussen (1982). Next, I review the fundamental premises of error training and potential reasons for the positive function of errors. Finally, I tease apart the three components of error training and discuss the potential impact of each of these elements. First, I discuss the instructional component of error training. I highlight the crucial role of exploration in error training and review past research on exploratory and discovery learning. Second, I discuss the motivational impact of make and avoid errors instructions. I highlight the similarities between these instructions and the concept of goal orientation. And, third, I review the emotional control component of error training and its potential impact on individuals' affective reactions. I note similarities between the heuristics incorporated into error training and several other techniques designed to control individuals' emotions, including emotional control strategies (Kanfer & Ackerman, 1990), rational attitude training (Ellis, 1977), and thought self-leadership (Neck & Manz, 1996a, 1996b). The conclusions drawn from this literature review will be integrated into a conceptual model and specific hypotheses concerning the instructional, motivational, and emotional effects of error training will be presented.

REVIEW OF THE LITERATURE

Active Learning

In most training programs, primary responsibility of learning functions is assumed by either the instructional system (e.g., instructor, computer program, etc...) or the learner (Simons & De Jong, 1992). In traditional training environments, most learning functions are accomplished by the instructional system. For example, an instructor may choose the learning activities and their sequence, present the information in a structured way, link new information to old, and monitor student progress and provide feedback. Of course the learner must still engage in a number of learning activities, such as encoding, storing, and retrieving information. However, in many ways the learner in this type of system is a passive recipient of the instruction because major educational decisions, such as choosing learning activities and judging progress, are made for him or her.

Traditional training approaches. This passive approach to training emerged from several different sources of influence. One major source was Skinner and other behaviorists, who argued for an errorless approach to learning. The behaviorists argued that errors were aversive stimuli that should be avoided because of their capacity to inhibit responding. In addition, errors were regarded as detrimental from an information perspective as it was thought that errors had to be unlearned before a correct action could be learned. As a result, Skinner (1954, 1958) developed programmed instruction from theories of positive reinforcement with the aim of eliminating the need for trainees to make mistakes. Programmed or proceduralized instruction involves tightly structuring a training program by breaking down the procedure for achieving a training goal into a series of steps. Trainees are guided through these steps so as to maximize the chances of

success and minimize the number of errors committed, and immediate feedback is provided to reinforce learning (Ford & Kraiger, 1995; Ivancic & Hesketh, 1995/1996).

Early programmed instruction systems included electronic machines that displayed material and whose buttons, when pressed, indicated the correctness of a response, as well as textbooks that provided spaces for responses to questions and typically displayed the correct answer on the next page (Latham, 1989). As computers became available, programmed instruction gave way to computer-assisted instruction (CAI) and intelligent tutoring systems. These computer-based instructional systems were grounded in the programmed instruction methodology (Cooley & Glaser, 1969). They used algorithms to judge individuals' progress and adapt to the needs and abilities of learners. In many ways, these early computer-based training systems epitomize the passive approach to training because the computer was responsible for all major educational decisions, such as the sequence, content, and pace of instruction (Steinberg, 1977, 1989; Williams, 1993).

For years, this passive approach dominated because the field of training had become increasingly reductionist in nature and overly reliant on behavioral paradigm principles (Ford & Kraiger, 1995). Training needs assessment techniques relied almost exclusively on reducing tasks down to their individual elements – knowledge, skills, and abilities – and training design, therefore, was often based on theories of identical elements and focused on developing specific skills (Ford & Fisher, 1997; Royer, 1979). In addition, training evaluation typically focused on behaviorally based measures of change and transfer was conceptualized as the reproduction of skills across environments, from training to the performance context (Kozlowski & Gully, 1996; Kraiger, Ford, &

Salas, 1993). Most training studies focused on developing routine expertise, which involves extensive and well-organized domain knowledge and procedural rules for addressing conditional problem states (Anderson, 1983; Holyoak, 1991). Under these conditions, proceduralized training proved quite effective. Research demonstrated that proceduralized training promotes the acquisition of specific skills and can also lead to transfer to problems which are relatively similar to those encountered in training (Frese, 1995; Clark & Voogel, 1985). In addition, it takes time for individuals to recover from errors, so errorless learning helped to significantly decrease the time taken to acquire declarative knowledge and proceduralized skills. Overall, proceduralized instruction was viewed as a rather effective technique for developing specific, reproducible skills in a short period of time.

Changing nature of work. Over time, however, the nature of work began to change. Advances in technology made jobs that once required lower level perceptual and motor skills more cognitively demanding (Tannenbaum & Yukl, 1992). Other changes occurring in the workplace such as team-based work systems, the focus on quality, and the movement towards reengineering all required a highly trained workforce (Ford & Fisher, 1997). These changes occurred rapidly and many work environments grew increasingly more dynamic and ill-structured. As a result, training was needed that could provide individuals with flexible, adaptable skills that they could apply to the novel problems they often faced on the job. In addition, the complexity of tasks required individuals to develop deeper or more comprehensive knowledge. It soon became clear that traditional training approaches were neither practical nor effective means of developing these types of knowledge and skills.

The traditional training perspective assumes that work environments are largely predictable and that training designs can be identified to prepare trainees to respond appropriately across routine job situations (Smith et al., 1997). For example, many traditional learning principles, such as overlearning, assume a task that requires some consistency of action. Others, like stimulus variability, assume that one is able to identify the range of situations for which the knowledge or skill is applicable. As the nature of work became more flexible and unpredictable, it grew increasingly more difficult to apply these traditional learning principles.

In addition, researchers started to recognize that many traditional learning principles, such as using massed training, providing immediate feedback, and using a constant training stimulus, may improve acquisition and immediate retention but have detrimental effects on long-range transfer and adaptability (Ford & Weissbein, 1997; Schmidt & Bjork, 1992). Research revealed that while routine experts are very effective at identifying the key characteristics of well-structured problems and implementing well-learned solutions, they have difficulty dealing with ill-structured and novel problems (Devine & Kozlowski, 1995). In fact, their highly organized knowledge and automatized performance patterns can be a liability in more flexible work environments (Hesketh, 1997). Sternberg and Frensch (1992), for example, found that routine experts are less able to adapt when deep structural principles of their problem domain change.

Adaptability. In the changing workplace, training that developed reproducible skills was no longer sufficient. What was needed was training that would also promote “far” transfer, or the generalization of learning across tasks, problem types, and contexts (Gick & Holyoak, 1983; Baldwin & Ford, 1988). The limitations associated with

traditional learning principles and routine expertise stimulated research on ways to promote adaptive expertise (Smith et al., 1997). Adaptive expertise builds on the foundation of routine expertise. It necessitates a deep comprehension of the conceptual structure of the problem domain; a flexible knowledge organization (Kozlowski & Gully, 1996). It also goes beyond procedural knowledge of an automatic sort. Adaptive experts understand when and why particular procedures are appropriate, and also when they are not (Ford & Kraiger, 1995; Smith et al., 1997). In contrast to routine experts, adaptive experts can invent new procedures based on their knowledge and make new predictions in response to changing task conditions (Hatano & Inagaki, 1986).

Whereas extensive practice and automatization are keys to developing reproducible skills and promoting near transfer (Shiffrin & Schneider, 1977; Salomon & Perkins, 1989), research has revealed that mindful processing and abstraction are critical for the development of adaptive expertise (Hatano & Inagaki, 1986; Salomon & Perkins, 1989). Mindful processing refers to the volitional, metacognitively guided employment of nonautomatic (controlled) processes (Salomon & Goberson, 1987). When mindful processes are evoked, the individual inhibits or withholds the evocation of a first, salient response (Pascual-Leone, 1984), examines and elaborates situational cues and underlying means that are task relevant (Kane & Anderson, 1978), generates or defines alternative strategies (Pressley, 1986), gathers information necessary for the choices to be made (Bandura & Cervone, 1986), or draws new connections and constructs new structures (Langer, 1985). Abstraction involves the extraction from or identification in a learned unit of material, in a situation or in a behavior, some generic or basic qualities, attributes, or patterns of elements (Salomon & Perkins, 1989). These extracted qualities are

decontextualized, which affords application to other instances. Thus, mindful processing and abstraction serve as mechanisms that provide a bridge from one context to another, thereby facilitating far transfer.

Active learning strategies. Numerous studies have attempted to develop adaptive expertise through traditional approaches to training. In these studies, a passive, deductive learning process is used and individuals are given the abstract formulations (e.g. principles, strategies, formulas) necessary for generalization. However, research has shown that for transfer to occur the abstraction must be genuinely comprehended, not just learned as a formula. In particular, the person must grasp the relationship between the decontextualized representation and the “raw” instances of which it is an abstraction (Gick & Holyoak, 1983). Indeed, active learning wherein people achieve abstractions by themselves, although not necessarily producing better learning outcomes, has been shown to facilitate farther transfer than so-called passive reception (Mayer & Greeno, 1972).

As a result, in recent years a number of new approaches to training have been developed to promote active learning and facilitate the development of adaptive expertise. These techniques include advance organizers, discovery learning, metacognitive training, mastery training, and error training. Although these various techniques are each somewhat unique, they also tend to share several similarities. For example, all of these techniques allow individuals to be active participants in their learning process and are designed primarily to engage individuals’ metacognitive and self-regulatory processes (Smith et al., 1997). In addition, these techniques promote an inductive learning process in which individuals must explore and experiment with the task to infer and learn the rules, principles, and strategies for effective performance

(Kamouri et al., 1986; Pearn & Downs, 1989; Smith et al., 1997). This approach to learning can be contrasted with the more traditional, deductive approach to training, which explicitly instructs individuals on the complete task and its concepts, rules, and strategies.

In the current study, I focused specifically on error training. Error training can be distinguished from more traditional training techniques in that it encourages trainees to make errors and views errors as critical for developing generalizable skills. However, recent research suggests that the benefits of error training may not arise from the process of simply making errors, but rather other elements associated with the general error training approach. In particular, error training promotes an exploratory, experimental learning environment, it incorporates learning goals, and, more generally, it facilitates an active, participatory approach to learning. In addition, error training incorporates emotion-control strategies. For example, error training incorporates emotion-control statements designed to control individuals' affect surrounding errors and poor performance. In the following sections, I provide a more detailed examination of error training and its instructional, motivational, and emotional elements. Before discussing error training, however, it is important to first understand the nature of errors and error detection.

Error Taxonomies

At a general level, errors can be defined as "all those occasions in which a planned sequence of mental or physical activities fails to achieve its intended outcome, and when these failures cannot be attributed to the intervention of some chance agency" (Reason, 1990; p. 9). In any work situation, constraints are found which must be

respected in order to perform satisfactorily. There are, however, also many degrees of freedom that have to be resolved at the worker's discretion. If this was not the case, the work environment would be totally predetermined, and there would be no need for human choice or decision. As individuals test the boundaries of acceptable performance and attempt to eliminate these degrees of freedom, errors are an unavoidable side effect (Rasmussen, 1990).

In recent years, the concept and analysis of human error in work settings has changed dramatically. Human activities in traditional work environments can be described in terms of repetitive tasks, such as the sequence of acts in control of some equipment or tool. Manufacturing systems were normally planned for effective and economic operation over long periods of time. Stable work patterns could be identified during design and by analysis of the task, and human errors could be easily defined. As workers acquired know-how, the "normal way" of doing things emerged and the perceived degrees of behavioral freedom were ultimately very limited (Rasmussen, 1990). By contrast, in modern workplaces, people are frequently moved to supervisory tasks in which decision-making and work activities are less repetitive. In these flexible and dynamic work conditions, the immediate degrees of freedom will have to be continuously resolved and it is more difficult to define errors as a specific set of behaviors (Rasmussen, 1990). As a result of these changes in the nature of work, the focus of error analysis shifted from overt acts to decision functions and further on to psychological mechanisms.

The application of psychological principles to the study of errors has resulted in several error taxonomies. These taxonomies are useful because they describe the variety

of forms errors can take and attempt to explain the processes underlying error production. In addition, understanding these processes also makes it easier to predict the conditions under which particular errors are most likely to occur. In the following sections, I describe three of these taxonomies. I begin with Rasmussen's (1982) skill-rule-knowledge framework. This framework describes three levels of performance and the types of errors that are most likely to occur at each level. I then review Reason's (1990) generic error-modeling system (GEMS). This conceptual framework is derived in large part from Rasmussen's framework, but focuses more specifically on defining the characteristics of different error types. Finally, I discuss a taxonomy developed by Frese and colleagues (Frese, 1989; Zapf, Brodbeck, Frese, Peters, & Prümper, 1992) that focuses specifically on errors in working with office computers. This taxonomy expands on the work of Rasmussen and Reason and has been used extensively in error training studies.

Rasmussen's skill-rule-knowledge framework. Rasmussen's (1982) model provides a tripartite distinction of performance levels and discusses the probable causes of errors at each level. The three levels of performance, skill-based, rule-based, and knowledge-based, refer to different cognitive control mechanisms and were developed based on a verbal protocol study of technicians engaged in electronic "trouble-shooting" (Rasmussen & Jensen, 1974). The three levels of performance correspond to decreasing levels of familiarity with the environment or task.

At the skill-based level, human performance is governed by stored patterns of preprogrammed instructions represented as analogue structures in a time-space domain (Reason, 1990). Behavior at the skill-based level "represents sensorimotor performance

during acts or activities that, after a statement of an intention, take place without conscious control as smooth, automated, and highly integrated patterns of behavior” (Rasmussen, 1986, p. 100). Errors at the skill-based level of performance are related to the variability of force, space, or time coordination, and typically occur due to inappropriate attentional monitoring (e.g., inattention or overattention). In other words, errors occur at the skill-based level because the person does not recognize changes in task characteristics and, as a result, launches an inappropriate and automatic procedural routine.

The rule-based level is applicable to tackling familiar problems in which solutions are governed by stored rules of the type *if (state) then (diagnosis) or if (state) then (remedial action)*. Errors at this level are typically associated with the misclassification of situations leading to the application of a wrong rule or with the incorrect recall of procedures. In contrast to the skill-based level, rule-based errors occur at a more conscious level of processing. Rule-based performance is called into play only after a person has become conscious of some externally or internally produced event or observation that demands a deviation from the current plan (Reason, 1990). The automatic response is no longer appropriate and the person engages in problem-solving activities. Rule-based errors, such as misinterpreting the situation, occur during the problem-solving process.

The final level of performance, the knowledge-based level, comes into play in novel situations for which actions must be planned on-line, using conscious analytical processes and stored knowledge. Essentially, the knowledge-based level is activated when the individual has “run out” of applicable problem-solving routines and is forced to

resort to attentional processing. Errors at this level typically result from resource limitations and incomplete or incorrect knowledge. In other words, either the person is unable to draw upon their existing knowledge base to solve the problem or that knowledge base is deficient in some respect.

As individuals acquire expertise, the primary focus of cognitive control moves from the knowledge-based toward the skill-based levels. However, it is important to recognize that all three levels can co-exist at any one time. Rasmussen identified eight stages of decision-making or problem solution: interpretation, evaluation, observation, identification, goal selection, procedure selection, activation, and execution. As individuals attempt to solve a problem, they may switch back and forth between the knowledge-based stages (interpretation and evaluation) and the rule-based stages (observation, identification, goal selection, and procedure selection). The switch from the rule-based level to the knowledge-based level occurs when problem solvers realize that none of their repertoire of rule-based solutions is adequate to cope with the problem. Once an adequate problem solution has been found, however, performance switches to the skill-based level and the solution is activated and executed.

Reason's GEMS. Reason's (1987, 1990) generic error-modeling system is derived in large part from Rasmussen's skill-rule-knowledge classification of human performance. However, whereas Rasmussen's model focuses on levels of performance and errors that occur at each level, Reason's model focuses more specifically on differentiating between different error types. He identified three types of errors - slips, lapses, and mistakes - which I describe below.

Slips are errors that result from some failure in the execution stage of an action sequence, regardless of whether or not the plan that guided them was adequate to achieve its objective (Reason, 1990). Slips are quite common and arise from moments of absent-mindedness. For example, a person intends to drive to the store but, out of habit, ends up driving halfway to work before recognizing the error. Slips are unintended actions; the error occurs because the person's actions deviate from his or her current intention. Two conditions appear to be necessary for the occurrence of slips: the performance of some largely automatic task in familiar surroundings and a marked degree of attentional capture by something other than the job in hand (Reason, 1979; Norman, 1981). Thus, slips arise from lower-level cognitive processes and can be related to Rasmussen's skill-based level of performance.

In many ways, lapses are similar to slips because they occur when a person fails to execute an intended action. In fact, slips and lapses are often grouped together into a general category termed "execution failures." However, in the case of lapses, the execution failure occurs not in the execution stage, but rather in the storage stage of an action sequence. For example, a person may decide they need to go to the store to get milk, put on their shoes, and then forget what they planned to do. Essentially, the error occurs in the storage of the intention. Lapses are more covert error forms because they do not necessarily manifest themselves in actual behavior and may only be apparent to the person who experiences them. Lapses can also be related to Rasmussen's skill-based level of performance and they often occur under the same conditions as slips (e.g., the person is interrupted and their attention is directed away from the current routine).

Even when intended actions proceed as planned, they can still be judged to be erroneous if they fail to achieve their intended outcome. In this case, the problem resides in the adequacy of the plan rather than in the conformity of its constituent actions to some prior intentions. Errors of this kind are called mistakes. Mistakes can be formally defined as “deficiencies or failures in the judgmental and/or inferential processes involved in the selection of an objective or in the specification of the means to achieve it, irrespective of whether or not the actions directed by this decision-scheme run according to plan” (Reason, 1990, p.9). In simple terms, mistakes occur because a person carries out a plan that is itself inappropriate or inadequate. Mistakes arise from the higher-level processes involved in intention formation. Specifically, Reason distinguishes between two types of mistakes, rule-based and knowledge-based, that correspond to Rasmussen’s performance levels. Rule-based mistakes occur when a person misclassifies a situation and, therefore, applies a rule (i.e., plan) that is inappropriate or deficient given current circumstances. Knowledge-based mistakes occur when a person develops an inappropriate plan either due to resource constraints (e.g., unable to access prior knowledge) or incomplete or incorrect knowledge.

Reason’s slips, lapses, and mistakes terminology has become standard verbiage among those interested in errors. Although the level of processing at which these different errors occur was specified by earlier theorists, Reason’s major contribution was incorporating the notion of intended and unintended actions. Essentially, if the intention is not appropriate, it is a mistake. But, if the action (or inaction) is not what was intended, this is a slip or a lapse. Another way of distinguishing these two basic error forms is as planning failures (mistakes) and execution failures (slips and lapses).

Frese's error taxonomy. The third and final taxonomy of errors I will review is the one developed by Frese and colleagues (e.g., Frese & Peters, 1988; Zapf et al., 1992; Zapf, Brodbeck, & Prümper, 1989). Although their taxonomy is based on action theory (Frese & Sabini, 1985; Hacker, 1986; Volpert, 1987), it is in many ways similar to the frameworks developed by Rasmussen and Reason. A unique contribution of Frese's taxonomy is that it focuses on errors in computerized work situations. Below, I describe Frese's taxonomy and the various human-computer interaction errors they identified.

A common assumption in action theory is that actions are goal oriented (Frese & Sabini, 1985). Within this approach, the action process consists of three steps: goal and plan development, the execution of actions as well as monitoring, and feedback processes. Goals and plans have to be developed first, then the plans are executed. To do this, subplans are typically stored in memory and recalled as needed to achieve subgoals. Monitoring environmental contingencies and one's own procedure is necessary in order to use the correct subplan at the right time. Finally, feedback is given on whether or not goals or subgoals were attained.

Action theory also distinguishes three levels of action regulation. These three levels are the intellectual level, the level of flexible action patterns, and the sensorimotor level, which correspond to Rasmussen's knowledge-based, rule-based, and skill-based levels, respectively. In addition, there is also a knowledge base for regulation, which involves knowledge of facts, knowledge of procedures, and understanding in the sense of mental models (Zapf et al., 1992). This knowledge is used to develop goals and plans.

Frese's taxonomy distinguishes errors according to the steps in the action process and the different levels of regulation. Eight different error types are identified using a

matrix that crosses these two theoretical dimensions. A single category of errors is identified for both the knowledge base level of regulation and the sensorimotor level of regulation. The authors argue that it is difficult to differentiate between planning, monitoring/execution, and feedback errors at these two levels. However, for both the intellectual level of regulation and the level of flexible action patterns, three categories of errors are identified based on the steps of the action process. These eight categories of errors are described below.

Errors that occur at the knowledge base of regulation are referred to as *knowledge errors*. These errors occur when one is unable to correctly carry out a task with the computer because one does not know certain commands, function keys, rules, and so forth (Zapf et al., 1992). These errors are similar to Reason's knowledge-based mistakes because they occur due to incomplete or incorrect knowledge. Errors that occur at the sensorimotor level of regulation are termed *sensorimotor errors*. These errors arise from stereotyped and automatic movements, such as clicking the wrong mouse button or typing an incorrect key. The sensorimotor level of regulation corresponds to Rasmussen's skill-based level of performance, and sensorimotor errors are the same as Reason's slips – they are unintended, automatic actions.

At the intellectual level of regulation (Rasmussen's knowledge-based level), three types of errors are identified that correspond to the planning, monitoring/execution, and feedback stages of the action process. *Thought errors* occur when goals and plans are inadequately developed or when wrong decisions are made in the assignment of plans and subplans although the user knows all the necessary features of the system. For example, a user tries to put a 12-column table on a single page, but then realizes the

columns are too wide. *Memory errors* occur when a certain part of the plan is forgotten and not executed, although the goals and plans were initially correctly specified. These errors are similar to Reason's lapses and occur due to a lack of monitoring or attention. For example, a person forgets to include an intended column in their table. The third type, *judgement errors*, appear when one cannot understand or interpret the computer feedback after an input.

Errors at the level of flexible action patterns occur when well-known actions are performed and can also be differentiated based on the three stages of the action process. *Habit errors* imply that a correct action is performed in a wrong situation. These errors are similar to Reason's rule-based mistakes and involve the misapplication of rules. For example, a person switches from Word to WordPerfect but uses the same function keys. *Omission errors* happen when a person does not execute a well-known subplan. This is most likely to occur when a person is interrupted in an action plan. For example, a user is interrupted by a phone call and subsequently forgets to save a file at the end of a session although he or she routinely does so. Finally, *recognition errors* occur when a well-known feedback message is not noticed or is confused with another one.

Summary. The previous sections described three taxonomies of errors. Although the taxonomies are each somewhat unique based on the researchers' orientations, they also share several commonalities. For example, all three distinguish between errors that occur at the skill-based, rule-based, and knowledge-based levels of performance. In addition, these taxonomies differentiate between errors that occur during action execution and those that occur during problem solving and plan development.

In the current study, I used these taxonomies to identify and classify the different types of errors individuals are likely to make as they proceed through training on the experimental task. In later sections, I will describe the nature of these errors and discuss their potential role in stimulating active learning processes. In addition, I will link these errors to specific skills being trained and describe how factors such as task complexity and stage of learning influence the types of errors that will emerge. Research suggests, for example, that execution failures (e.g., slips and lapses) are more likely on basic tasks because actions are routine and regulation occurs at lower-levels. However, planning failures (e.g., mistakes) are more likely on strategic or complex task components because goals and plans have to be developed and decisions at this level are difficult (Reason, 1990). In addition, early in training most errors emerge from incorrect or incomplete knowledge and occur at a higher-level of regulation. However, as training progresses and individuals acquire knowledge and compile that knowledge into proceduralized rules, an increasing number of errors occur at lower-levels of regulation and inappropriate attentional monitoring is a major source of errors.

The relationship between task characteristics and error type is also important because different types of errors may have different implications for learning and, therefore, error training may be better suited for training different types of skills or tasks. Active learning techniques, including error training, are typically viewed as effective means of developing more complex and adaptive skills. However, for the most part, past research on error training has used relatively basic and proceduralized tasks, such as word processing or database search programs. On such tasks, a large percentage of errors occur at lower-levels of regulation. Of course, some errors occur at higher levels of

regulation, especially early in training as individuals develop task knowledge. But, for the most, the transition to automatic, proceduralized performance occurs rather quickly on these tasks and, therefore, lower-level errors, such as clicking a wrong mouse button or forgetting a command, tend to dominate training. As a result, the effectiveness of error training for developing more complex and strategic skills, which involve a larger percentage of planning failures, has been largely unexamined.

In the current study, individuals will be required to learn a number of both basic and strategic skills. By including training on both basic and strategic skills, the present study provides a test of the effectiveness of error training for developing different types of skills. Some research suggests that error training may be more effective for training complex skills because a greater number of errors are made and, therefore, the impact of error training on learning is greater (Frese, 1995). These errors may stimulate active learning processes, such as metacognitive activity and hypothesis-testing, that, in turn, may facilitate the development of a deeper knowledge structure, creative problem solutions, and task strategies, all of which should prove useful on more complex tasks.

Although error training may be particularly useful for developing more complex skills, it is important to recognize several potential pitfalls. For example, research suggests that the higher-level mistakes or planning failures associated with complex skills require greater resources (e.g., time, attention, etc...) to correct than lower-level slips or lapses (Zapf et al., 1992). On the one hand, this increased attention and mindfulness can facilitate learning. However, it is also important to recognize that a large number of higher-level errors can be detrimental because individuals may be overwhelmed. This may be particularly true for trainees with lower levels of ability. Also important is the

issue or error detection. Obviously, for an error to serve a positive function in the learning process it must be detected. In addition, error detection is important because it allows an individual to correct the mistake and exit the error situation. When an error goes undetected, the person not only fails to learn from the mistake but the negative consequences of the error may accumulate and influence other events downstream. Research suggests, however, that not all errors are detected and that higher-level errors are more difficult to detect than lower-level slips and lapses, which are almost always realized (Reason, 1990). Thus, when using error training to develop more complex skills, it is important to consider whether the errors that occur will be detected and used in the learning process. In the next section, I discuss the issue of error detection in more detail.

Error Detection

An error is only of psychological relevance to an individual once it has been detected (Zapf et al., 1992). It is not making the error that is beneficial for learning, but rather the information that the error provides and the learning processes and activities they stimulate. Errors serve a feedback function. They highlight violations of rules and alert learners to problem features that cannot be changed without altering the solution procedure (Ivancic & Hesketh, 1995/1996). In addition, errors remind learners of past failures and the reasons why they occurred. Thus, errors can only stimulate learning if an individual recognizes that he or she has erred. In addition, error detection is critical for error handling because the sooner a person recognizes that an error has occurred, the quicker he or she can correct the situation and potentially avoid the negative consequences associated with the error. In the following sections I discuss the issue of

error detection in more detail, focusing specifically on the detectability of different types of errors and sources of error detection.

Detecting different types of errors. Although many errors are immediately recognized by those who make them, not all errors are detected. In fact, most major accidents (e.g., Challenger explosion, Three Mile Island, Chernobyl) have resulted from a series of relatively minor and undetected errors, often called latent failures (Reason, 1990). These errors gradually build on one another and eventually the series of events results in a disastrous outcome. Despite the obvious importance of error detection, there is very little in the way of empirical studies of error detection or of theories to explain the processes by which people catch and correct errors made by themselves or by others.

The few studies that have examined the issue of error detection have typically used very specific tasks such as reading (Carpenter & Daneman, 1981), writing (Hayes & Flower, 1980), or solving statistical problems (Allwood & Montgomery, 1981, 1982). Only a few investigators have examined error detection in real-life settings and many of these studies have been conducted in high reliability organizations, such as nuclear power plants. Woods (1984), for example, reviewed data from 99 test scenarios, using 23 crews in 8 different failures at nuclear power plants. Nearly two-thirds of all errors went undetected. A higher rate of error detection was found by Bagnara, Stablum, Rizzo, Fontan, & Ruo (1987) in their study of steel mill operators. Eight experienced operators were required to carry out a simulated production planning exercise and their work was videotaped and analyzed by the experimenters and task experts. This research revealed that 95 errors were made and 74 of them were detected. Overall, error detection rates have typically been found to fall somewhere between 70 and 90 percent.

One interesting finding that has emerged from studies on error detection is that the rate of detection tends to depend on error type. For example, Reason (1990) examined the results of three studies on error detection (Allwood, 1984; Bagnara et al., 1986; Rizzo, Bagnara, & Visciola, 1986) and found the overall detection rates to be 86.1% for skill-based errors, 73.2% for rule-based errors, and 70.5% for knowledge-based errors. Other studies have reported even larger differences in error detection rates between various error types. Woods (1984), for example, found that while half of the execution failures (slips and lapses) were detected by crews, none of the state identification failures (rule-based and knowledge-based mistakes) were discovered.

These results provide support for the idea that higher-level errors are more difficult to detect than lower-level errors (Reason, 1990). It has been suggested that mistakes are harder to detect than slips and lapses because consciousness is specifically tuned to picking up departures of action from intention (Mandler, 1975), but mistakes can pass for lengthy periods and even when detected they sometimes remain a matter of debate. This is due to the fact that the quality of a plan is a more subjective evaluation. We typically evaluate a plan based on how well it achieved its objectives. If the mistake is not evident in the outcome, however, it may be difficult to recognize the error because the actions proceeded as planned. In addition, the mistake may not have an immediate effect on the outcome, also making it more difficult to recognize the error.

These findings are critical because different types of errors may be more or less important in training. Although lower-level errors are rather easily detected, they typically result from an aberrant physical response or a temporary lapse of attention and, when discovered, are rather easily corrected. Thus, the information provided by lower-

level errors and their potential impact on individuals' learning processes may be limited. Higher-level errors, on the other hand, are often more complex and difficult to resolve because they emerge from poor planning or a lack of knowledge. But, the process of trying to understand or correct these errors may yield a great deal of information and stimulate mindful learning. At the same time, however, higher-order errors are considerably more difficult to detect. These results suggest that the type of errors that may ultimately have the greatest impact on individuals' learning are those that are most difficult to detect. This has important implications for designing systems that provide maximum opportunity for error detection.

Source of error detection. There are three ways in which people's errors are brought to their attention. First, they can find out for themselves through various kinds of self-monitoring. Second, something in the environment makes it very clear that something has gone wrong. Or third, the error is discovered by another person who then tells them. In the current study, we are interested in the first two modes of error detection, self-discovery and environmental error cuing.

Research suggests that the self-monitoring of errors in problem-solving situations can take three forms (Allwood, 1984). First, individuals can engage in a standard check (SC). These checks are initiated independent of the specific properties of the previous work and the individual simply decides to carry out a general check on progress. Second, errors can be detected during an episode called direct error-hypothesis formation (DEH). These episodes are triggered by an abrupt detection of a presumed error. They need not occur immediately after the error was made, nor do they necessarily discover actual errors. Finally, errors can be detected due to error suspicion (ES). Here the individual

notices something unusual, and suspects that an error has been made. In contrast to DEH where the person presumes a specific error, in ES the person is initially focused on some property of the solution rather than a precise cause for concern.

As the results discussed earlier indicate, self-monitoring is fairly effective for realizing lower-level errors. Research suggests that individuals detect around 90% of their skill-based errors without any assistance. These are usually fairly easy to detect because the action that occurs is not what was intended and the person has immediate information that something has gone wrong. As a result, slips are typically discovered through DEH (Rizzo et al., 1986). At the same time, however, research also suggests that self-monitoring is not as effective for discovering higher-level errors. Self-monitoring typically produces error detection rates of about 70% for rule-based and knowledge-based errors. Thus, when dealing with higher-level errors, it is often necessary to create systems that will assist individuals in error detection.

There are many ways in which the environment can inform us that we have made an error. Sometimes these cues are the natural part of a task. For example, the most common environmental error cues are what have been called “forcing functions” (Lewis & Norman, 1986). Forcing functions essentially prevent a behavior from continuing until the problem has been corrected. For example, if we have not made all the necessary connections in the wiring of an electrical appliance, it will not work. Appropriate forcing functions guarantee error detection, because the person’s onward progress is blocked by the error. Although environmental error cues can be a natural part of a system, oftentimes they are built into systems by designers to help individuals detect their errors.

Lewis and Norman (1986) identified six possible ways in which a system can respond to its operators' errors. For example, computer systems can incorporate "gagging" functions, which are essentially forcing functions that prevent users from expressing incorrect intentions. For instance, if a user attempts to type in an illegal command, it is not accepted. Another type of system response is warnings. Warnings inform individuals of potentially dangerous situations, but allow the individual to decide what he or she wants to do. Systems can also incorporate "do nothing" mechanisms, in which the system simply does not respond to illegal input. And of course, systems can interpret individuals' actions and provide explicit feedback to help a user recognize his or her errors. Although the usefulness of these systems obviously depends on the quality of the information provided to individuals, there is some evidence to suggest that external support systems can be extremely useful in enhancing the detection of higher-level errors (Woods, 1984).

Summary. Overall, it is important to recognize that not all errors are detected, especially when the only source of error detection is self-monitoring. This is particularly true when dealing with higher-level rule-based and knowledge-based mistakes. Individuals tend to be fairly proficient at recognizing when their actions have deviated from their intentions (e.g., slips and lapses). But, research suggests that planning failures are much more difficult to detect not only because their impact may not be immediately evident but also because the evaluation of a plan of action is often a subjective process and open to interpretation. As a result, when tasks are more complex and involve a greater number of higher-level errors, it is often important to incorporate system functions that assist individuals in error detection. These functions, such as gagging or

do nothing mechanisms, provide clear information to indicate that an error has been made.

As I mentioned earlier, the issue of error detection is important within the context of error training because errors can only serve a positive function in the learning process if they are recognized. Frese and Altmann (1989), for example, noted that individuals had the most trouble interpreting feedback concerning errors that occurred at the intellectual level of regulation. Oftentimes, individuals were unable to determine the nature of the error and therefore could not correct it. As the authors state, “Since they could not interpret the feedback correctly, they were unable to find a solution to the situation” (Frese & Altmann, 1989, p. 73). For error training to be effective, therefore, it is important to make sure that individuals can detect and evaluate the errors they make.

In the current study, individuals learned how to operate a complex and dynamic radar-control simulation. The simulation presented participants with multiple targets on a computer screen. Participants needed to learn to “hook” targets on the radar screen and collect information to classify the target’s characteristics. This information is used to make a number of sub-decisions about each target as well as a final overall decision on whether the target should be shot down or cleared from the screen. In addition, there are two perimeters located on the radar screen and participants needed to learn how to identify and prevent targets from crossing these perimeters.

Several steps were taken to increase error recognition and diagnosis as participants practiced the radar-control simulation. First, the experimental simulation provided individuals with immediate feedback after they prosecute each target. This allowed individuals to recognize when they made an incorrect decision. Second, the

simulation incorporated several forcing functions that allow individuals to recognize when they have violated the basic operating rules of the system. For example, if individuals did not make the sub-decisions for a target in the appropriate order, the system prevented them from making a final decision. Third, individuals were given a list of common errors that are made on the task. This strategy has been used in several error training studies to help individuals recognize the errors that can occur on the task (Frese, 1995). Finally, individuals were provided detailed feedback following each practice trial on the number and types of errors they made. This feedback is especially useful for helping individuals to recognize and diagnosis errors on more complex aspects of the task (e.g., preventing perimeter intrusions).

In the following sections, I provide a review of past empirical and theoretical work on error training. I first outline the fundamental principles of error training. I then describe the instructional, motivational, and emotional control elements of error training and examine the potential impact of these elements on various training processes and outcomes.

Fundamental Principles of Error Training

There are two strategies that can be used to deal with errors in training, error prevention and error training. Historically, there have been more theoretical and empirical arguments for an error prevention approach. Skinner (1968) explicitly argued for error prevention because errors were assumed to work like punishment. Erroneous behaviors not only disrupt good performance but also may produce negative attributions that demotivate trainees. Therefore, programmed learning was developed to eliminate errors from training. Humanistic approaches have also been critical of errors because it is

thought that learning might be impeded by the anxiety and frustrations that accompany making errors (Frese, 1995). As a result, errors have traditionally been given a “bad name” in the training literature.

The alternative strategy is error training. Error training is often referred to as error management, because the focus of this approach is not on eliminating errors but rather reducing or managing the negative consequences associated with errors (Frese, 1995; Frese & Altmann, 1989). This approach differentiates between the error itself and the negative error consequences. Frese and colleagues argue that the problem is not that individuals make errors, but that they suffer negative consequences as a result. Error management, therefore, suggests that errors per se do not have to be avoided or minimized – just the negative error consequences.

Why, though, should errors be managed rather than eliminated? One reason is that research suggests that errors are ubiquitous and that it is futile to attempt to eliminate errors through better knowledge. Prümper, Zapf, Brodbeck, & Frese (1992), for example, have shown that experts make as many errors as novices. In fact, under certain conditions and with certain errors, experts err more often. In their study, individuals who knew more than one computer program made 5.83 errors per hour, but those who knew just one program only made 3.87 errors per hour (Prümper et al., 1992). Research also suggests that experts are more prone to slips, lapses, and rule-based mistakes than novices because they engage in automatic, as compared to controlled, information processing (Reason, 1990). This is important because research suggests that the large majority of total errors occur at the skill-based and rule-based levels (Reason, 1990). In addition, at work one usually does not have the support that one receives during the

training sessions and, as a result, errors tend to be a normal part of actual work situations (Frese, 1995). Since errors can rarely be eliminated in real-world situations, the error management perspective argues that it is more important to examine the negative consequences associated with these errors, such as the amount of time lost as the person corrects their mistake or the negative impact errors have on individuals' self-image. The goal of training should be to reduce these negative consequences, not the errors themselves.

Several researchers have also argued that the error management approach to training offers potential instructional, motivational, and emotional advantages over more traditional, proceduralized training approaches. There are three main features of error training strategies that distinguish them from more traditional, error prevention strategies. First, error training involves an exploratory learning environment, which can be contrasted to the structured and proceduralized learning environment found in programmed instruction. Second, error training instructs individuals to make errors. Traditional training typically encourages trainees to avoid errors. Finally, error training incorporates heuristics that are designed to reduce the anxiety and frustration that typically accompany errors. These three features or elements of error training have potential instructional, motivational, and emotional implications. In the following sections, I briefly highlight several of the potential implications of error training for learning, motivation, and emotional reactions.

Instructional/Learning implications of error training. One potential reason to include errors in training is that research suggests that errors can be useful in helping individuals develop accurate mental models (Manktelow & Jones, 1987). An error serves

as feedback as to what the person does not yet know. Errors also alert trainees to incorrect assumptions in their mental model and provide the impetus for updating and revising the model (Rasmussen, 1990; Waern, 1993; Katzeff, 1990), as well as highlighting the boundaries of a system (Frese & Zapf, 1994). Thus, not allowing errors to appear in training reduces feedback for the trainee. Moreover, mental models are better when they also encompass potential pitfalls and error-prone problem areas (Frese, 1995).

Errors may also enhance learning by provoking attention-dependent information processing (Ivancic, 1998; Ivancic & Hesketh, 1995/1996). The early stages of skill acquisition are characterized by controlled processing and error-prone performance; however, with increased practice, knowledge about the task can be compiled into procedures so that performance becomes more automatic and relatively error-free (Anderson, 1983). Errors may enhance learning because they can cause learners to switch from relatively effortless automatic processing to effortful controlled processing (Frese et al., 1988; Frese & Altmann, 1989; VanLehn, 1991). Therefore, errors can extend the period of time in which a skill is practiced using controlled processing (Frese et al., 1988), a condition that fosters schema extraction and the learning of principles (Sweller, 1988) and prevents the premature automatization of a skill (Frese, 1995; Frese & Zapf, 1994). Errors may activate controlled processing because they tend to be novel and unexpected events and therefore involve a surprise reaction. Surprise is one of the conditions thought to induce mindfulness (Salomon & Globerson, 1987), and several models of learning have emphasized the ability of surprising or unusual stimuli to generate learning (e.g., Holyoak, Koh, & Nisbett, 1989). As discussed earlier, mindful

processing is also viewed as necessary for the development of generalizable knowledge and skills.

Several aspects of error training may also promote exploration, creativity, metacognitive activity, and hypothesis-testing, which in turn may enhance learning. Sometimes errors themselves can spur creative solutions to a problem and increase exploration (Frese, 1995). When an error occurs, the person may be led to a part of the system he or she did not know before and start exploring to find a better way of doing things. Thus, errors may instigate exploration. When error-free training is desired, the trainer will restrict the kind of strategies used by trainees and the material they focus on during training. However, in error training, individuals are allowed to explore the domain and are encouraged to develop and test hypotheses about the task. This exploration and hypothesis-testing allows individuals to develop more flexible skills and a deeper knowledge structure, which can facilitate the transfer of knowledge and skills (Frese et al., 1988). In addition, since individuals are in control of their learning they are more likely to engage in self-regulatory and metacognitive activities as they make various learning decisions, such as judging progress and determining what content to study and practice (Smith et al., 1997).

A final instructional advantage of error training may emerge from the fact that errors have the potential to aid transfer by reminding trainees of analogous problems and the strategies that were successful in resolving problems (Ivancic, 1998; VanLehn, 1991). Errors may also aid retrieval because they are distinctive and therefore easily recalled (Cormier, 1987; Read & Cesa, 1991). In other words, by making errors during training individuals will be better equipped to avoid and handle those errors in the future.

Research by Gick & McGarry (1992), for example, found that students who made errors in solving an initial problem were more likely to succeed on an analogous transfer problem than participants who solved the initial problem correctly. Allowing individuals to make mistakes that are accompanied by feedback will be more beneficial than providing a correct representation of a problem aimed at avoiding errors, particularly if problem solving with the potential for errors is required later (Gick & McGarry, 1992; Goldman, 1991).

It is important to recognize that the majority of these instructional advantages are not tied directly to the nature of the errors themselves. Although errors can provide valuable information, simply making an error does not necessarily result in enhanced knowledge or skills. Rather, the benefits arise when the errors stimulate particular learning processes or activities, such as hypothesis-testing, self-regulation, and the updating of one's mental model. This is the fundamental premise of error management - errors are not necessarily detrimental and can, in fact, be advantageous to learning if utilized properly. The problem is that these instructional benefits are often negated by a host of negative motivational and emotional implications that stem from errors.

Motivational implications of error training. Errors have typically been avoided in training due to their potentially negative motivational implications. Errors have a motivational significance because they indicate that a previous action was unsuccessful (Dutke & Schonpflug, 1987). The discrepancy between trainees' desired goal and actual performance can influence both their satisfaction with past performance and their confidence in their ability to achieve future goals (Kanfer, 1990). The negative reactions that accompany errors may cause individuals to give up exploring the task or may make

them withdraw from the task altogether. At a more general level, when errors are viewed negatively they will make a task less interesting and fun (Frese, 1995). A major goal of error training, therefore, is to mitigate these negative motivational consequences of errors.

In traditional training, errors produce negative reactions because they are perceived as something to avoid. Since the goal is error-free performance, errors indicate a failure to achieve the goal and evoke negative attributions. A major goal of error training, therefore, is to reframe errors and change the way people react to making errors. In error training, errors are not only encouraged but are also framed as an important part of the learning process. Thus, when an individual makes an error he or she can interpret it as a positive experience. Essentially, in error training “the goal changes from not-wanting-to-make-an-error to let-me-see-what-I-can-learn-from-this-error” (Frese & Altmann, 1989, p. 82).

Several researchers have suggested that this reframing of errors may have positive motivational implications. It has been argued, for example, that framing errors as beneficial occurrences may increase trainees’ intrinsic motivation (Nordstrom et al., 1998). When errors are framed negatively, a reduction in trainees’ intrinsic motivation may occur because errors are seen as punishment and as a form of extrinsic constraint (Deci, 1971). However, if it is beneficial to make errors, then error occurrence should not deflate motivation. In addition, the exploratory nature of error training provides individuals with greater control over their learning, which may also enhance intrinsic motivation.

Research also suggests that framing errors as positive experiences helps to create a learning or mastery orientation (Dweck & Leggett, 1988; Ivancic, 1998). Under learning oriented conditions, individuals tend to view failure as controllable and perceive problems and errors as challenges (Dweck, 1986). By contrast, traditional training tends to create a more performance-oriented environment in which failure is seen as uncontrollable and an indication of low ability. As a result of these attributional differences, individuals who adopt a learning orientation will typically expend greater effort and will persist longer in the face of failure than individuals who are performance oriented.

Emotional implications of error training. Errors have an upsetting and frustrating quality (Frese & Altmann, 1989). As discussed above, this stems largely from the fact that errors are typically perceived as something to avoid and are therefore evaluated negatively when they occur. The anxiety and frustration that surrounds errors can be detrimental because these emotions divert attentional resources away from on-task activities. This assumption underlies the Cognitive Interference Hypothesis in which performance deficits following failure are thought to be due to anxiety-related cognitions that divide attention (Mikulincer, 1989). A major goal of error training, therefore, is to reduce the negative emotions that often accompany errors.

One way error training attempts to reduce anxiety and frustrations is by reframing errors, as discussed above. It is thought that if individuals are encouraged rather than discouraged from making errors, they will experience less anxiety and frustration when they make errors. It is also thought that by including errors in training, individuals will become more error tolerant. As Frese and Altmann (1989, p. 82) state, “The trainee

simply gets used to making mistakes and, therefore, the errors lose some of their threatening characteristics.” When errors are viewed as a more natural or normal part of learning, they should be less upsetting (Frese, 1995). Although these two aspects of error training almost certainly impact individuals’ emotions, the greatest emotional advantage of error training is thought to emerge from the presentation of emotion-control statements.

These statements, or as Frese and colleagues call them “heuristics,” are designed to directly reduce the anxiety and frustrations that typically accompany errors. These statements specify that one should learn from errors and that one should take errors as an indication that one can learn something new (Frese, 1995). They are designed to not only create a mastery orientation but also to get people to think rationally about errors. Examples of these statements are “I have made an error. Great!” or “There is always a way to leave the error situation.” These emotion-control statements are viewed as integral to error training and are seen as providing a major emotional advantage over more traditional training techniques (e.g., Heimbeck, Frese, & Sonnentag, 2000). As Frese (1995, p. 119) stated, “It seems that our use of heuristics in the error training group had indeed helped to defray the negative frustrations due to errors.”

Summary. Numerous arguments have been presented to support the concept of error training. Practically, it has been suggested that error-free training is unrealistic. Errors occur in actual work situations and, therefore, should be included in training so that individuals learn how react to and handle errors when they arise. Theoretically, it has been argued that error training provides numerous instructional, motivational, and emotional advantages when compared to more traditional training approaches. For

example, error training is thought to enhance the development of more accurate mental models, promote exploration and hypothesis-testing, facilitate intrinsic motivation and task persistence, and reduce the anxiety and frustrations that typically accompany errors.

Despite these numerous arguments, we still have little idea of how error training has its effects. This is due, in part, to the fact that very few of the potential mechanisms discussed above have been examined in empirical research. A few studies have examined the role of exploration in error training (e.g., Dormann & Frese, 1994), and a few studies have looked at intrinsic motivation (Nordstrom et al., 1998) and frustration (Frese et al., 1991). However, the large majority of arguments presented above have not been formally tested. Moreover, past research has tended to combine the various features of error training strategies into a single manipulation. As a result, it is extremely difficult to evaluate what is actually producing the observed effects. For example, does error training increase exploration because it provides an unstructured learning environment or because individuals are encouraged to make errors and test their hypotheses? Similarly, are the emotional advantages of error training due to the emotion-control statements or “make errors” instructions? Currently, we do not know the answers to such questions.

To truly understand how error training has its effects, two things must be done. First, research must tease apart the instructional, motivational, and emotional elements of error training so that the independent and interactive effects of these components can be evaluated. For example, the effects of “make errors” instructions must be distinguished from the effects of statements that promote positive and rational thinking. Second, research must identify the various mechanisms by which these different elements may impact learning and performance. By identifying these mechanisms and including them

in research, it will be possible to formally test the arguments presented above and increase our understanding of how error training has its effects. Thus, in the following sections, I turn attention to decomposing the instructional, motivational, and emotion-control elements of error training and identifying the means by which these elements may impact training outcomes, such as learning and performance.

Instructional Element of Error Training

Past research on error training has typically used one of two methods to induce errors in the learning process. In some studies, trainees in the error-training condition have been given problems that exceed their level of ability (Frese & Altmann, 1989; Frese et al., 1991). While this method is rather effective for generating errors, it is somewhat problematic because it confounds error training with task difficulty. As a result, the majority of research on error training has manipulated errors through the nature of instruction. Individuals in the error training condition are provided an unstructured learning environment and are encouraged to explore the task. Although they may be given the basic instructions or commands, the error training group typically receives very little guidance. This active, exploratory learning environment increases the chances of errors. In contrast, individuals in the error avoidant group receive more passive, proceduralized instruction. They are given detailed, step-by-step instructions and all the commands necessary to perform the task (e.g., Dormann & Frese, 1994; Frese et al., 1988; Frese et al., 1991; Nordstrom et al., 1998). Proceduralized instruction greatly reduces the number of errors that individuals make as they proceed through training. Although this alternative method for producing errors does not confound error training

with task difficulty, it raises separate issues concerning the impact of these different types of instruction.

An active and exploratory approach to learning is viewed by many as a critical element of error training. In fact, some researchers have gone so far as to suggest that exploratory learning and error training operate via the same mechanisms. Greif and Janikowski (1991), for example, labeled their active instructional approach “exploratory learning through errors.” A study by Dormann and Frese (1994) examined whether the performance advantages of error training are due to the exploration that is inherent in such training. They found not only that the error training group outperformed the error avoidant group but also that exploratory behavior partially explained the superiority of error training. It appears, then, that exploration is indeed an important component of error training.

Over the years, a considerable amount of research has compared exploratory learning and proceduralized instruction. This research suggests that exploratory learning facilitates an active, mindful approach to learning, which in turn often leads to increased learning, performance, and generalization. It is not surprising, therefore, that Dormann and Frese (1994) found that exploration partially mediated the relationship between error training and performance. What is interesting, however, is that past research on error training has not focused more attention on examining the role of exploratory learning in error training. Considerable research suggests that exploratory learning may influence performance through a number of the instructional mechanisms identified earlier as potentially important in error training, such as hypothesis-testing, strategy development,

and effortful processing. Despite these apparent associations, the impact of the exploratory component of error training on these mechanisms has not been examined.

Therefore, in the following sections I review past research on exploratory learning and identify the mechanisms by which exploratory learning is thought to impact learning and performance. I then discuss the potential instructional implications of an active, exploratory learning approach specifically in error training. Finally, I highlight the potential role that task complexity may play in determining the relative effectiveness of this instructional component of error training.

Exploratory learning. Exploratory learning (also called discovery learning) refers to the acquisition of new information through activities initiated and controlled by the learner (Kamouri et al., 1986). It is an inductive learning process in which individuals must explore and experiment with the task to infer and learn the rules, principles, and strategies for effective performance (Kamouri et al., 1986; Pearn & Downs, 1989; Smith et al., 1997). Exploratory learning can be contrasted with the more traditional, deductive approach to training which explicitly instructs individuals on the complete task and its concepts, rules, and strategies.

Researchers have described several theoretical reasons for the benefits of exploratory learning. First, exploratory learning may increase individuals' motivation. It has been argued that individuals in an exploratory learning setting are more motivated because they are responsible for learning and they are engaging in an active learning process (Singer & Pease, 1976). In traditional instructional approaches, individuals are explicitly taught the correct task procedures, and then they practice the application of the procedures. In contrast, individuals in an exploratory learning setting must discover the

correct task strategies on their own. This makes the task more challenging and also gives trainees significant control over their learning, which may, in turn, enhance motivation.

Exploratory learning may also promote the development of task strategies (Veenman, Elshout, & Busato, 1994). McDaniel and Schlager (1990), for example, suggest that in the course of attempting to discover strategies and/or the steps to implement the strategies, the learner may also develop procedures that help to generate novel solutions strategies and/or combinations of steps. People in exploratory learning conditions try a number of strategies. Although many of these strategies will be wrong for the current problem, they might be appropriate for a new problem. As McDaniel and Schlager (1990, p. 151) state, “solving a remote-transfer problem might be accomplished by applying a strategy that produced a dead end in the training problems.” Also, since people explore and test different strategies during training, they will be better equipped to recognize when a particular strategy is ineffective and they need to develop a new solution for a transfer problem (McDaniel & Schlager, 1990).

Exploratory learning also facilitates the use of hypothesis-testing and problem-solving skills. As individuals explore a task, they typically do not engage in blind trial-and-error. Rather, exploration is often based on hypotheses and guided by some kind of mental model (Carroll, Mack, Lewis, Grischkowski, & Robertson, 1985; Greif & Keller, 1990). As individuals test their hypotheses, they increase their understanding of the relational structure of the domain and revise their mental model (Rasmussen, 1990). Hypothesis-testing can be very valuable for learning because research has shown that “eliminative” tests that show a particular problem solution is wrong are very helpful for discovering the correct solution (Klayman & Ha, 1989). Furthermore, individuals who

use hypothesis-testing approaches during training will have these strategies available to them when they face a novel transfer situation and must search for a new response (McDaniel & Schlager, 1990).

Since individuals must develop a solution to the task on their own, the knowledge they acquire through exploratory learning becomes better integrated into their existing knowledge (Egan & Greeno, 1973; Frese et al., 1988). Individuals begin with a rudimentary conceptualization of the system, which guides their initial exploration. The more it is possible to integrate new information into these already existing conceptualizations, the better they are able to learn (Frese et al., 1988; Volpert, 1987). This knowledge is also more flexible because the active processing and mindfulness that occurs during exploratory learning leads to acquisition of knowledge at a higher level of regulation (Frese & Zapf, 1994; Salomon & Perkins, 1989). Proceduralized instruction, on the other hand, is often based on a very concrete representation of the problem-solving actions, which may encourage individuals to represent the problem domain at an inappropriate level of abstraction (Carlson, Lundy, & Schneider, 1992; Simons & DeJong, 1992).

A final benefit claimed for exploratory learning is related to the type of knowledge acquired during training. Exploratory learning allows individuals to make errors and, therefore, individuals learn from not only performing the task correctly but also from making mistakes (Ivancic & Hesketh, 1995/1996; Singer & Pease, 1976). Making mistakes leads to the development of a better operative mental model of the task (Frese et al., 1988). As individuals explore the task and make errors, they are able to incorporate potential pitfalls and error-prone areas into their mental model (Frese, 1995).

In addition, exploration exposes individuals to a wider range of task material. Although some of this material may not be applicable to the current problem, it may prove useful when individuals are required to transfer their knowledge and skills and solve a novel problem.

In general, empirical research has provided support for the benefits of exploratory learning. An early review of exploratory learning studies indicated that exploratory learning (inductive learning) leads to greater transfer than rule-example methods of instruction (deductive approach) (Hermann, 1969). In addition, the review noted that exploratory learning was particularly effective for transfer over longer time periods and for transfer tasks that were more complex and novel. More recent research not only supports the conclusions of this early review but also provides a better idea of how exploratory learning has its effects. Below I discuss several of the findings of these recent studies.

Frese and colleagues (1988) compared proceduralized instruction and exploratory learning for training individuals on a word processing system. They found that in comparison to sequential or programmed instructions, individuals in an exploratory learning condition had greater recall of task commands, were able to deal with errors quicker, and had more integrated and flexible mental models. As would be expected based on these findings, individuals in the exploratory learning condition also exhibited better transfer performance (Frese et al., 1988).

Kamouri et al. (1986) compared an exploration-based condition, in which individuals experimented with three analogous simulated devices in order to discover the procedures governing their operations, to an instruction condition, in which individuals

followed procedural examples contained in manuals. Results revealed that the exploration-based condition led to greater transfer on a novel device two days later and also enhanced recall of the three training devices' operations. Overall, the results indicate that exploration-based training promoted the use of analogical reasoning in knowledge transfer and facilitated the induction of abstract device representations (schemas).

McDaniel and Schlager (1990) hypothesized that exploratory learning should be most beneficial when individuals need to develop new strategies to solve transfer problems. They conducted an experiment in which they taught individuals how to solve water-jar problems. The exploratory condition required individuals to figure out both the general strategy and the specific move sequences for these problems. In the comparison condition, individuals were given the general strategy and had to discover the specific move sequence. Consistent with their expectations, they found that on a near transfer task that involved a similar strategy, both groups performed about the same. On the far transfer task, however, the exploratory learning group outperformed the group that was given the strategy during training. The authors argue that exploratory learning helps people to develop new strategies in similar knowledge domains. Additional analyses, for example, revealed that all subjects attempted to apply their training strategies to the transfer problem; however, participants in the exploratory learning condition were quicker to generate an alternative strategy.

Smith (1996) compared the effectiveness of discovery learning, guided discovery learning, and proceduralized instruction for training on a complex radar simulation. Although she found evidence that discovery learning increased hypothesis-testing and

self-regulation during training, discovery learning did not increase adaptive transfer. Verijken and Whiting (1990) compared discovery learning to several different training methods (e.g., providing individuals with a model) for learning slalom ski-type movements on a ski-simulator. Results revealed that discovery learning was more effective than all of the other training methods, and the authors suggest that this is because discovery learning forces the learner to explore the dynamics of the system in an iterative fashion. Finally, Long and Warner (1979) compared the impact of programmed learning and discovery learning on individuals' attitudes. They found that students rated the discovery learning approach significantly higher than the programmed learning approach in terms of feelings of motivation, degree of learning, level of enjoyment, and overall impression of the learning approach.

In summary, researchers have described several theoretical reasons for the benefits of exploratory learning and empirical research has provided support for many of these arguments. Although exploratory learning has been shown to influence individuals' motivation, its primary impact is instructional in nature. For example, exploratory learning has been shown to promote analogical reasoning and schema abstraction (Kamouri et al., 1986), increase hypothesis-testing and self-regulation (Smith, 1996), facilitate the generation of task strategies (McDaniel & Schlager, 1990), and lead to more flexible and comprehensive mental models (Frese et al., 1988). As a result, exploratory learning often leads to increased knowledge and performance, especially on novel problems that require new strategies and problem solutions.

Exploratory learning in error training. Hiltscher and Frese (1994) note the similarities between training involving errors and exploratory or discovery-based

training. Both offer relatively unstructured environments in which trainees actively develop a knowledge base. Furthermore, as Ivancic and Hesketh (1995/1996) argue, learning in both error training and exploratory learning “is an ‘error filled’ experience in which trainees engage in exploration, problem-solving, hypothesis testing, making mistakes, and, in the case of computers, learning how to recover from their errors” (p. 106). It is not surprising, therefore, that error training and exploratory learning are thought to operate through many of the same mechanisms (Dormann & Frese, 1994). In the following sections, I discuss the potential role of exploratory learning in error training. Since past research has not decomposed the various elements of error training, it is somewhat difficult to determine the precise influence of exploratory learning in error training. However, I will attempt to show that many of the effects of error training are the same as those discussed above for exploratory learning and, therefore, most likely emerge from the same sources.

Dormann and Frese (1994) conducted a study designed to directly examine whether exploration explains the positive benefits of error training. Participants learned several rudimentary commands in the SPSS statistical analysis software and performed a few basic statistical calculations. One group of participants received error avoidant training, in which they were given detailed written instructions specifying each step and command to be used. These individuals were discouraged from exploring the task and the experimenter quickly corrected any errors that were made. The other group of participants received standard error training. This group was not given any detailed instructions, but did receive a leaflet with a short description of the commands needed to

solve the tasks. In addition, the error training group received a set of three emotion-control statements designed to counter the frustrating quality of errors.

Dormann & Frese (1994) found that the two groups performed about the same on the easy tasks, but the error training group performed significantly better on the more complex statistical operations. They also found that exploratory behavior was positively related to performance and that exploration partially mediated the relationship between error training and performance. Thus, it appears that exploration is an important element of error training, but not the only element.

Although Dormann and Frese (1994) is the only study to directly examine the role of exploration in error training, the results of several other studies suggest that the active, exploratory approach of error training is important. Frese et al. (1991), for example, compared the effectiveness of error training and error avoidant training for teaching individuals how to operate a word processing program. Once again, the error training group was instructed to explore the task and received little guidance, and the error avoidant group was given proceduralized instruction. Consistent with Dormann and Frese (1994), the results revealed that the error training group performed significantly better on the more difficult aspects of the task. Furthermore, Frese et al. (1991) suggest that superiority of error training may emerge from the fact that individuals in the error training condition developed more accurate mental models, had higher motivation, and engaged in a deeper level of processing. All of these explanations are consistent with the effects of exploratory learning reviewed earlier.

A study by Irmer, Pfeffer, and Frese (1991) also provides some evidence of the role of exploratory learning in error training. In this study, three variations of error

training were applied to an existing, three-day software training program, which normally was structured to reduce the number of errors. Two findings of this study are of interest. First, the authors found that teaching strategies for error handling was not more effective than the general error training method. Thus, the superiority of error training does not appear to emerge from being taught specific strategies to deal with errors. Rather, it seems that the benefits of error training are derived from some aspect of the general error training approach. Second, Pfeffer (1992) performed a fine-grained key stroke analysis of the Irmer et al. (1991) data and found differences in the way the error training and error avoidant group explored the task. Individuals in the error avoidant group who explored the task despite the proceduralized nature of instruction tended to use exploration in a more trial-and-error sense. In contrast, individuals who received error training used exploration in a more hypothesis-driven way. Together, these findings suggest that the superiority of error training may emerge from the fact that it promotes an exploratory, active approach to learning, which, in turn, facilitates hypothesis-testing.

Two studies by Ivancic also shed light on the potential role of exploratory learning in error training. Ivancic (1998) performed a series of studies to examine several of the potential mechanisms thought to explain the benefits of error training. She found evidence that error training promotes deeper and more effortful processing, positively impacts the development of schema and rules, and helps to cue the retrieval of previously used strategies. Although she did not tease apart the exploratory element of error training, all of these results are consistent with the effects of exploratory learning. In another study, Ivancic and Hesketh (in press) examined whether individuals could benefit by passively observing the errors of others. One group of participants learned by actively

making errors on a driving simulation, while the other group watched a videotape of individuals making similar errors. The researchers found that drivers who actively made their own errors performed better on an analogical transfer test than drivers who observed the errors of others. Thus, it appears that the active, exploratory component of error training has incremental value over and above the information provided by errors.

Finally, a study by Wood et al. (2000) investigated the effects of enactive exploration on intrinsic motivation, strategy, and performance on an electronic search task. Enactive exploration is similar to error training and includes elements of self-guided exploration and error management. Compared to individuals who received more proceduralized instruction, trainees in the enactive exploration condition exhibited higher levels of intrinsic motivation and better performance. In addition, participants who received enactive exploration worked more efficiently, taking less time to complete the transfer task. Wood et al. (2000, p. 280) suggest that “the combined effects of self-guided exploration and the positive framing of feedback may affect learning and performance through several different cognitive and affective causal pathways.”

In summary, very few studies on error training have directly examined the impact of the active, exploratory approach supported by such training. However, numerous studies have revealed that error training often produces effects similar to those found in studies on exploratory learning. As a result, it is likely that error training and exploratory learning operate via many of the same mechanisms. More specifically, it seems that the exploratory learning component of error training may have a significant influence on hypothesis testing, strategy development, cognitive effort, and intrinsic motivation. Research also suggests that task complexity and several individual differences may

moderate the effects of exploratory learning on learning and performance. I discuss these issues in the following sections.

Exploratory learning and task complexity. Several researchers have argued that the effectiveness of exploratory learning may depend on the complexity of the task being trained; however, it also appears that there is some disagreement concerning the exact nature of this relationship. A number of researchers have suggested that exploratory learning should be more effective for learning more basic tasks. Debowski, Wood, and Bandura (2001), for example, found that exploratory learning that involved errors was not beneficial for learning a complex search task. The authors suggest that the complexity of the task made ineffective strategies difficult to detect and, therefore, limited the effectiveness of exploratory learning. However, the problem does not seem to be directly related to exploratory learning, but rather the fact that individuals did not receive enough information to facilitate error detection. Ivancic (1998) and Ivancic and Hesketh (1995/1996) also suggests that error training should be more effective for simpler tasks because resource demands are lower. They suggest that many of the benefits of exploratory learning, such as hypothesis-testing and mindful processing, may not be realized when tasks are complex and attentional resources are scarce. Finally, McDaniel and Schlager (1990) suggest that exploratory learning may be inappropriate or too inefficient for learning the knowledge that underlies performance in complex domains. They argue that some knowledge may just be too complex to learn through pure discovery.

An alternative argument is that exploratory learning may actually be more beneficial for learning complex skills. Clark and Voogel (1985), for example, argue that

more basic, procedural tasks lend themselves to training by errorless learning and other traditionally behaviorist techniques, whereas more cognitively-based and complex tasks that require conceptual knowledge or the development of a mental model and strategies are better suited to exploratory learning. Similarly, Heimbeck et al. (2000) suggest that since basic tasks typically involve fewer errors and a low degree of knowledge and skill, the type of training does not matter very much. However, they argue that because difficult tasks require a greater degree of knowledge and skill, the positive impact of error training (and its exploratory approach) on learning and performance should be more pronounced.

Empirical research tends to lend greater support to the argument that exploratory learning is more effective on complex tasks. On more basic tasks, there tends to be little difference between exploratory learning and proceduralized instruction in terms of learning and performance (e.g., Frese, 1995; McDaniel & Schlager, 1990). However, for more complex tasks, individuals who receive exploratory learning often exhibit increased learning and performance compared to those who are given proceduralized instruction (e.g., Dormann & Frese, 1994). Frese (1995), for example, noted that most studies have found error training to be more effective for complex tasks than for simple ones. Most likely, the impact of task complexity on the effectiveness of exploratory learning is curvilinear in nature, such that exploratory learning is most beneficial for tasks that are moderately complex and least beneficial for tasks that are fairly basic or extremely complex.

Motivational Element of Error Training

A second important element of error training involves the instructions that trainees are given. In traditional training programs, trainees are discouraged from making errors. Essentially, traditional training frames errors negative occurrences that should be avoided because they will inhibit learning and performance. In error training, however, individuals are encouraged to make errors. Error training uses error encouragement to reframe errors as serving a positive function in the learning process. In simple terms, traditional training programs encourage trainees to avoid errors, while error training encourages trainees to make errors.

The “make errors” instructions provided in error training are thought to have important motivational implications. In traditional training programs, errors are viewed as something to avoid; therefore, they are more likely to be interpreted negatively when they occur. When errors are framed negatively, a reduction in trainees’ motivation may occur because errors are seen as punishment and as a form of extrinsic constraint (Deci, 1971). In addition, when individuals are focused on avoiding errors they may be less motivated to engage in learning activities, such as exploration and experimentation, that increase the potential for making errors (Dormann & Frese, 1994). Error training, however, uses “make errors” instructions to reframe errors as positive learning experiences. Researchers have argued that error encouragement stimulates exploration and experimentation, because trainees view mistakes as less aversive and, therefore, are more willing to engage in learning activities that involve errors (Dormann & Frese, 1994; Ivancic & Hesketh, 1995/1996). Along similar lines, reframing errors as positive

experiences may also potentially reduce the negative motivational and emotional consequences typically associated with errors (Frese, 1995).

Although error encouragement is viewed as a critical component of error training, past research typically has not isolated the impact of “make errors” instructions. One exception is a recent study by Gully et al. (2002) which focused on interactions between make and avoid errors instructions and several individual differences. However, the Gully et al. study examined the direct impact of error-encouragement on several training outcomes, such as declarative knowledge and performance, and did not attempt to explain the processes by which error encouragement may impact these outcomes. Furthermore, in the Gully et al. study all trainees received the same type of instruction (guided exploration) and emotion-control statements were not used. As a result, we still do not fully understand the motivational role of error-encouragement within the overall error training approach.

The present study examined the independent effects of “make errors” instructions on a number of relevant training processes and outcomes. It is critical to distinguish the effects of error-encouragement from the effects of related aspects of error training, particularly exploratory learning. For example, both error-encouragement and exploratory learning are thought to stimulate exploration and experimentation and enhance intrinsic motivation, so it is important to distinguish the impact of these two elements and determine the relative importance of each in promoting the positive effects of error training. In the following sections, I discuss how error encouragement and error avoidance relate to the concept of goal orientation. I then discuss the potential role of “make errors” instructions specifically in error training.

Error encouragement and goal orientation. Goal orientation is a construct originating in the educational literature that suggests that individuals hold either a learning or performance orientation toward tasks (e.g., Dweck, 1986, 1989). A learning orientation is characterized by a desire to increase one's competence by developing new skills and mastering new situations. In contrast, performance orientation reflects a desire to demonstrate one's competence to others, be positively evaluated by others, and avoid failure (Farr, Hofmann, & Ringenbach, 1993).

Research has shown that the two types of goal orientation differentially influence how individuals respond to task difficulty and failure (Dweck, Hong, & Chiu, 1993; Dweck & Leggett, 1988; Elliott & Dweck, 1988). Individuals with a learning orientation tend to pursue what researchers have called an adaptive response pattern. This response pattern is characterized by persistence in the face of failure, the use of more complex learning strategies, and the pursuit of difficult and challenging material and tasks. Performance orientation, however, is associated with what researchers have called a maladaptive response pattern. This response pattern is characterized by a greater propensity to withdraw from tasks (especially in the face of failure), less interest in difficult tasks, and the tendency to seek less challenging material and tasks on which success is likely and failure can be avoided.

Research has found that goal orientation is linked to an individual's implicit theory of ability (Button, Mathieu, & Zajac, 1996; Dweck & Leggett, 1988). Individuals with a performance orientation tend to hold an *entity* theory about their ability; they view ability as a fixed, uncontrollable personal attribute. In contrast, individuals with a learning orientation tend to hold an *incremental* theory about their ability; they view

ability as a malleable attribute that can be developed through effort and experience. Moreover, it has been argued that the adaptive and maladaptive response patterns associated with the two types of goal orientation emerge on the basis of these different beliefs about ability (Dweck et al., 1993). With a learning orientation, for example, effort is viewed as a means for activating current ability for task achievement and as a means for developing the ability needed for future task mastery. With a performance orientation, however, ability is perceived as a fixed attribute. Therefore, individuals with high levels of performance orientation are unlikely to view effort as a means for developing the ability needed for task mastery.

Although goal orientation has typically been treated as a trait-like variable, research has also shown that learning and performance orientations can be activated by situational characteristics, such as goals (Bell, Mullins, Toney, & Kozlowski, 1999; Kozlowski et al., 2001; Kraiger, Ford, & Salas, 1993). Research suggests, for example, that goals that focus trainees' attention on learning objectives embedded in training experiences, rather than achieving specific outcomes, may be effective for creating a state learning orientation (Kozlowski, Gully, Smith, Nason, & Brown, 1995; Stevens & Gist, 1997; Winters & Latham, 1996). Essentially, these mastery type goals encourage trainees to focus attention on developing the skills needed for task proficiency and understanding deep task principles (Elliott & Dweck, 1988; Dweck, 1986). In contrast, performance goals focus trainees' attention on superficial task strategies that lead directly to better training performance, without exploring alternative task strategies that may be critical to developing deep conceptual knowledge. In addition, performance goals tend to stress errorless performance and the demonstration of one's competence to others.

A considerable amount of research over the past decade has demonstrated the relationship between goal orientation and the affective, cognitive, and behavioral reactions of individuals in achievement settings, such as the classroom and in athletics (e.g., Duda & Nicholls, 1992; Dweck & Leggett, 1988). In addition, research has shown that goal orientation has important implications in training and employment contexts (e.g., Fisher & Ford, 1998; VandeWalle, Brown, Cron, & Slocum, 1999; VandeWalle & Cummings, 1997). Consistent with the idea of an adaptive response pattern, research has generally shown that learning orientation is associated with more positive outcomes, such as increased self-efficacy, motivation, and performance (e.g., Colquitt & Simmering, 1998; Ford, Smith, Weissbein, Gully, & Salas, 1998; Phillips & Gully, 1997; VandeWalle et al., 1999). In contrast, performance orientation has typically displayed more mixed effects, sometimes negative, sometimes positive, and other times equivocal (e.g., Button et al., 1996; Fisher & Ford, 1998; Phillips & Gully, 1997).

Partially in response to the inconsistent findings surrounding performance orientation, Elliot and colleagues (Elliot 1997; Elliot & Church, 1997) proposed an alternative, three-dimensional conceptualization of goal orientation. They conceptualized learning orientation similar to Dweck's original definition, but performance orientation was partitioned into separate approach and avoidance dimensions. The approach dimension was defined as striving towards normative competence, and the avoid dimension was defined as striving to avoid normative incompetence. Based on this three-dimensional view, VandeWalle (1997) developed and validated a three-dimensional measure of goal orientation that consists of learning orientation, performance-prove orientation, and performance-avoid orientation.

Given that the three-dimensional conceptualization of goal orientation only emerged within the past couple years, research comparing the effects of performance-prove and performance-avoid orientations has only recently started to emerge in the published literature. Elliot originally proposed that because avoid orientation is undergirded by fear of failure it would lead to negative outcomes, while prove orientation is undergirded by both need for achievement and fear of failure and should, therefore, lead to more positive outcomes (Elliot, 1999; Elliot & Church, 1997). Most studies that have utilized this three-dimensional conceptualization have found support for the negative effects of avoid orientation (e.g., Brett & VandeWalle, 1999; Dobbins, Bell, & Kozlowski, 2002; Schmidt & Ford, 2002; VandeWalle, Cron, & Slocum, 2001). However, the results for performance-prove orientation have been less clear. Although performance-prove orientation has not been shown to have negative effects, it appears that the competing motives that underlie performance-prove orientation produce positive effects in some situations and null relationships in other situations (VandeWalle et al., 2001). Until more work is conducted, it will be difficult to make strong predictions concerning the effects of performance-prove orientation.

Given the important role of goal orientation in determining individuals' affective, cognitive, and behavioral reactions, it is important to consider the influence of error encouragement and error avoidance on individuals' goal orientation. Traditional training programs typically promote error avoidance and orient individuals toward outcome goals, that is, a specific quantity or quality of something to be achieved (Winters & Latham, 1996). This focus on avoiding errors and achieving a particular outcome creates a performance-avoid orientation. In addition, error avoidance frames errors as an

indication of low ability and poor performance, which is characteristic of a performance orientation more generally (Dweck, 1986; Dweck & Leggett, 1988). Finally, instructions that discourage errors naturally promote an avoid orientation; individuals strive to avoid errors so as not to disprove their competence. The overall result is that error avoidance promotes a performance-avoid orientation and, therefore, the effects of error avoidance instructions in error training should be similar to the effects of performance-avoid orientation (e.g., decreased self-efficacy, lower intrinsic motivation).

Error encouragement, on the other hand, is typically viewed as a critical component of learning environments. Mastery training, for example, attempts to stimulate active learning by promoting learning goals, which encourage trainees to explore complex relations in the task, make errors, and learn from those errors (Kozlowski et al., 1995; Stevens & Gist, 1997). Error encouragement reframes errors as positive learning experiences and helps to switch the focus from performance to learning and understanding. In addition, error encouragement is inherently learning oriented, because errors are framed as challenges that individuals should learn from and overcome rather than avoid. Thus, error encouragement should produce positive effects similar to those found for learning orientation.

Whether and how the two types of error instructions will stimulate a performance-prove orientation is really an open question. Clearly, the two types of error instructions best represent a distinction between learning and avoidance and, therefore, they may not have much of an influence on trainees' performance-prove orientation. However, error encouragement is also more approach oriented than error avoidance because individuals are encouraged to use errors as an opportunity to learn and perform well. Thus, error

encouragement may stimulate and error-avoidance may restrict a performance-prove orientation. The data from the current study should help to clarify these competing alternatives. In the next section, I discuss the potential role of error encouragement specifically within the context of error training.

Error encouragement and error training. It has been argued that the superiority of error training may be due, at least in part, to the motivational effects of error encouragement. Frese et al. (1989), for example, argue that error encouragement reframes errors as positive experiences, which, in turn, reduces the negative motivational effects of errors. They suggest that errors are only frustrating and demotivating when they are seen as negative events and as something to avoid. Similarly, Henderson (1986) suggests that how errors influence individuals' self-efficacy and other affective reactions is dependent on the subjective meaning of errors.

Past research has provided some support for the motivational benefits of error encouragement. Frese (1995) notes that observations from their studies suggest that the error training group is typically more motivated than the error avoidant group. For example, people in the error training group often spend more time in training and want to work on the task after the experiment has ended. In addition, Frese (1995) reports that individuals in the error training condition often ask more questions. Nordstrom et al. (1998) found that individuals given make errors instructions had higher intrinsic motivation than individuals provided avoid errors instructions and Ivancic (1998) found that error training led to lower motivation early in training but increased motivation later in training.

Although it appears that error training influences individuals' motivation, the fact that past research has confounded the various elements of error training once again makes it difficult to determine whether these motivational effects are due to "make errors" instructions or some other aspect of error training, such as the exploratory learning environment. However, drawing on past research on the related concept of goal orientation, it is likely that the nature of error instructions has important motivational implications. Error avoidance can be described as promoting a performance-avoid orientation and error encouragement can be characterized as representing a learning orientation. Based on the literature reviewed above, these differences in the nature of make and avoid errors instructions should relate to differences in trainees' motivation. In addition, although the impact of error encouragement may be primarily motivational in nature, past research on goal orientation suggests that error encouragement may impact a number of additional outcomes that have as of yet been unexamined in error training research.

Research has shown that individuals with a learning orientation tend to display higher levels of self-efficacy than individuals with a performance orientation (e.g., Ford et al., 1998; Phillips & Gully, 1997). Also, Henderson (1986) suggests that when errors are viewed as learning experiences rather than as indications of low ability or poor performance, they may have a positive impact on individuals' self-efficacy. Thus, error encouragement may lead to higher levels of self-efficacy than error avoidance.

Research has also shown that goal orientation can influence individuals' affective reactions. Individuals with a learning orientation tend to display more positive affect than individuals with a performance orientation (Bell, Kozlowski, & Dobbins, 2001;

Elliott & Dweck, 1988; Jagacinski & Nicholls, 1987). These results suggest that error encouragement, which promotes a learning orientation, may lead to more positive affective reactions than error avoidance, which promotes a performance-avoid orientation.

Emotion-Control Element of Error Training

The third and final element of error training involves the statements, or heuristics, that are aimed at controlling individuals' emotions surrounding errors. Almost all of the studies on error training have included some type of emotion-control statements. Common examples include "I made an error. Great!" and "There is a way to leave the error situation" (e.g., Frese, 1991). These statements, which are typically displayed on a poster or an overhead projector, are designed to not only create a mastery orientation but also to get people to think rationally about errors. It has been argued that these statements help to reduce the anxiety and frustration that typically accompany errors (Heimbeck et al., 2000).

Although most studies on error training have included the emotion-control statements, it is difficult to determine whether the heuristics are a valuable component of the error training strategy. This difficulty stems, in part, from contradictory research findings. For example, Frese et al. (1991, p. 90) stated, "From our qualitative observations, we think that the positive effects of errors are partly due to presenting and repeating the heuristics." However, in his later review of research on error training, Frese (1995, p. 119) claimed, "However, we were not able to replicate this result in other studies" and "At this point in time, I have become more skeptical of the emotional hypothesis." A recent study by Heimbeck et al. (2000) provides some resolution to this

disagreement. Heimbeck and colleagues examined error training with and without the emotion-control statements and found evidence that the statements are crucial for the superiority of error training.

Although the Heimbeck et al. (2000) study suggests that the emotion-control statements may be an important element of error training, it provides little indication of why this may be. For example, Heimbeck and colleagues did not measure individuals' affect, despite the fact that the statements are designed to target individuals' emotions. In addition, Heimbeck et al. found that the statements did not influence individuals' state goal orientation. Other error training studies have measured individuals' affect (e.g., frustration); however, these same studies have not directly examined the impact of the statements. Finally, the emotion-control statements in Heimbeck et al.'s study explicitly encouraged individuals to make errors, so it is again difficult to partition the potential sources of influence. Thus, it is impossible to determine whether differences in trainees' level of frustration, for example, are due to the emotion-control statements or some other aspect of error training. Overall, the majority of previous research has tended to view the emotion-control statements as a necessary and critical component of the error training strategy. Yet, both theoretical and empirical work on error training fail to provide convincing evidence regarding the importance of the emotion-control statements and the mechanisms through which they have their effects.

In the current study, therefore, I attempt to distinguish the impact of the emotion-control heuristics from the other elements of error training. In addition, I examine several mechanisms that may potentially explain how the heuristics impact learning and performance. In the following sections, I provide a brief discussion of negative emotions,

their impact on performance, and techniques commonly used to reduce stress and anxiety. I then focus attention on three specific emotion-control techniques: Rational Attitude Training, Kanfer and Ackerman's emotion-control intervention, and Thought Self-Leadership. These techniques attempt to influence individuals' mental process in much the same way as the error training heuristics. Therefore, research on these interventions may provide insight into the mechanisms by which the heuristics have their effects. Finally, I provide a more detailed review of the role of the emotion-control heuristics in error training.

General overview of emotion-control techniques. Research has shown that cognitive activity serves as an important mediating variable between a stimulus and an emotional response, such as stress or anxiety (McGrath, 1970). Essentially, negative emotions occur when an individual makes a cognitive appraisal that a substantial imbalance exists between perceived environmental demands and perceived response capability. Numerous factors, including attributions and expectancies, can influence an individual's perception of his or her response capability. For example, individuals with a more internal locus of control are more likely to believe they can meet situational demands and are, therefore, less likely to experience debilitating anxiety than individuals with a more external locus of control (DuCette & Wolk, 1973).

Negative emotions typically have a detrimental impact on learning and performance, although there may be some instances in which moderate levels of stress or anxiety actually enhance performance. A number of researchers have argued that emotions such as anxiety and frustration are usually detrimental because they divert attentional resources away from on-task activities (e.g., Wood et al., 2000). Kanfer and

Ackerman (Kanfer & Ackerman, 1989; Kanfer, Ackerman, Murtha, Dugdale, & Nelson, 1994), for instance, have argued that negative affect consumes attentional resources and limits learning and performance, especially in the early stages of training when cognitive demands are high. Mikulincer (1989) makes a similar claim in his Cognitive Interference Hypothesis, which argues that performance deficits following failure are due to anxiety-related cognitions that divide attention. Finally, a number of studies have shown that state anxiety results in limited information processing capacity, decreased sensitivity to informational cues, and confused patterns of decision making (Catell & Schier, 1961; Spielberger, 1966).

Due to the detrimental effects of negative emotions on learning and performance, numerous techniques have been developed with the aim of controlling individuals' emotions. Given the important mediating role of cognitive activity in the relationship between a stimulus and an emotional response, it is not surprising that many of these interventions focus on influencing individuals' cognitions. Cue controlled relaxation, for example, teaches people to use self-produced cue words such as "relax" or "calm" to reduce multiple anxieties (Barrios, 1978; Benson, 1975). These cue words influence individuals' thought patterns and create a "cognitive barrier" between stressful events and negative emotional responses. Cognitive modification is another technique that is designed to focus individuals on the relationship between cognitions and emotional, behavioral, or physiological responses to stress (e.g., Horan, Hacket, Buchanan, Stone, & Demchik-Stone, 1977). If individuals understand such relationships they may be better equipped to manipulate them. Finally, guided mental imagery, which has individuals imagine positive events or good performance, has been used to influence individuals'

thought processes. Guided mental imagery can be used for relaxation, stopping negative thoughts, or reinforcing positive thought patterns. Research has shown that guided mental imagery can reduce feelings of anxiety and frustration and can help to eliminate self-defeating thoughts (e.g., Carter & Kelly, 1997; Mace & Carroll, 1985; Murphy & Woolfolk, 1987; Sapp, 1994).

Although research suggests that these cognitive-based interventions can have a significant influence on individuals' affect and performance, one limitation of many of these programs is that they tend to require a considerable amount of training time. A typical intervention, for example, may involve five or six two-hour instructional sessions (Rose & Veiga, 1984). These sessions often focus on outlining the physiological and psychological mechanisms of stress, teaching individuals how to identify anxiety or stress cues, and instructing and practicing the particular emotion-control skills. In many real-world training environments, this type of time commitment is just not feasible.

As a result, a number of researchers have begun to examine whether simpler interventions may be able to significantly influence individuals' emotions. Kanfer and Ackerman (1990), for example, simply instructed individuals to replace negative thoughts with positive thoughts, maintain a positive "Can do" attitude, and not worry about their performance early in training. As I will discuss in more detail shortly, they found that this simple technique had a significant impact on trainees' affect and performance. Bloom (1985) outlined a program designed to alleviate computer-anxiety. Although the total program is rather intensive and spans nine modules, he suggests that trainees can be taught rather straightforward techniques to help them control their distracting thoughts. For example, he suggests that trainees can be taught to repeat rational statements (e.g.,

“Remember, worry won’t help anything.”) to replace worrisome statements. Although more intensive programs probably produce greater emotional benefits, these relatively simple emotion-control strategies may offer economical alternatives when time is limited.

In the following sections, I describe in greater detail three interventions that have been used to control individuals’ emotions. On the surface, these interventions are quite different from the emotion-control statements used in error training research. However, as I will try to demonstrate, the fundamental processes through which these interventions operate are quite similar to those that form the basis of the error training statements. For example, all of these techniques attempt to replace individuals’ negative thoughts with positive thoughts and attempt to have people think rationally about mistakes and poor performance. After I have reviewed these various interventions, I will examine in greater detail the issue of emotion-control in error training.

Rational Attitude Training. Rational Attitude Training (RAT) is an affective intervention that is based on Ellis’ (1962, 1977) Rational Emotive Theory. Ellis argued that emotions are not caused simply by events that an individual experiences, but rather by the thoughts that the individual has after experiencing the events. More specifically, Ellis argued that irrational self-statements produce psychological distress and rational self-statements lead to appropriate emotions. Based on this theory, RAT is designed to make trainees aware of how their irrational thinking habits produce stress reactions and emotional responses.

In RAT, trainees are taught how to control stress-inducing thought patterns and are taught how to dispute irrational stress-producing beliefs and values (Lester, Leitner, & Posner, 1984). RAT involves teaching trainees to control their non-productive

questioning habits (why is this happening to me?), their use of 'magical' thinking (if I believe it to be, it will be!), their use of the demanding 'should' (I should be able to do this by now), and their use of unrealistic thinking (everybody will think I am stupid!). Trainees are taught how to eliminate these stress-producing attitudes and how to replace them with attitudes that promote effective problem-solving. One popular way to do this is to have trainees repeat rational statements. Research has shown, for example, that reciting rational statements, such as "If I am not performing as well I would like it is not terrible," or positive statements can help to reduce individuals' anxiety (Cramer & Kupshik, 1993; Rosin & Nelson, 1983), increase their self-efficacy (Milliman & Latham, 1996), and improve their performance (Van Raalte et al., 1995).

Although a bit more simplistic, the error training statements take an approach to emotion-control that is very similar to RAT. It has been argued that a major goal of the statements is to get individuals to think rationally about errors (Frese, 1995). Similar to RAT, the emotion-control statements stimulate rational thought by having individuals replace their irrational and unproductive thoughts surrounding errors, such as "If I make an error, everybody will think I am stupid," with more positive and productive thoughts, such as "I made an error. Great!" While error training typically does not instruct trainees to repeat these statements, the basic idea is that if trainees are exposed to the statements they will incorporate them into their thought patterns. It is for this reason that the emotion-control statements used in error training are typically framed in the first-person.

Kanfer and Ackerman's emotion-control intervention. Kanfer and Ackerman have also examined the impact of incorporating an emotion-control intervention into training. The intervention developed by Kanfer and Ackerman is similar to Rational

Attitude Training in that it is designed primarily to increase the frequency of positive thoughts and decrease the frequency of negative or irrational thoughts. Trainees are told not to worry about their task performance early in training and not to be distracted by the errors that they make. Further, trainees are instructed to increase the frequency of positive thoughts and to reduce the frequency of negative emotions, such as worry or upset following errors (Kanfer & Ackerman, 1996). Individuals receive instruction on the emotion-control strategy prior to initial task performance, and between trials they are given emotion-control reminders such as “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” (Kanfer & Ackerman, 1990).

Kanfer and Ackerman (1990) found that this emotion-control intervention had positive effects for low ability trainees, but did not benefit high ability trainees. Low ability trainees given the emotion-control intervention exhibited increased performance, reported fewer negative affective reactions, and made fewer attempts to monitor their performance score. Kanfer and Ackerman suggest that low ability individuals benefited the most from the intervention because they were more likely to make errors, perform poorly, and, therefore, experience negative affect. In addition, the authors found that the beneficial effects of the emotion-control intervention were most pronounced during the early stages of task performance. Once again, this is when task demands are the greatest and poor performance and errors are most likely. As Kanfer and Ackerman (1996, p. 168) state, “Emotion-control skills refer to self-regulatory patterns aimed at reducing the diversion of attentional resources to emotional concerns, and are most useful when attentional demands of the task are high.”

Overall, research suggests that Kanfer and Ackerman's rather simple emotion-control intervention is effective for minimizing the performance anxiety, worry, and off-task distractions that occur when a learner confronts frustrations and failures during the most difficult and demanding initial stages of skill acquisition. This is important because people with good emotion-control can maintain motivation and resist being sidetracked by self-blame or anticipation of negative consequences for performance failures, while people with poor emotion-control skills compound the difficulty of learning a new task by being distracted by worry and anxiety (Kanfer & Ackerman, 1996).

The similarities between Kanfer and Ackerman's intervention and the error training statements should be evident. First, both attempt to substitute individuals' negative thoughts with more positive and rational thoughts. Kanfer and Ackerman do this by directly telling individuals to replace their negative thoughts with positive thoughts. The emotion-control statements used in error training are a bit subtler, but the goal is the same. Second, both emotion-control strategies view errors as a major source of anxiety and worry and attempt to influence how individuals respond to failure. Kanfer and Ackerman's intervention tells individuals not to worry about making mistakes early in training, while the error training statements frame errors as positive experiences. Finally, both emotion-control strategies attempt to increase individuals' feelings of control. Kanfer and Ackerman directly instruct individuals to adopt a "Can Do" attitude, while in error training the statement "there is a way to leave the error situation" is used to minimize feelings of helplessness and increase feelings of control.

Thought Self-Leadership. Self-leadership is the process of influencing oneself to establish the self-direction and self-motivation needed to perform (Manz, 1983, 1986,

1992). This concept has been derived primarily from the social learning literature (Bandura, 1977, 1986) and related work in self-control (Bandura, 1969; Mahoney & Arnkoff, 1979). In the organizational literature, the primary focus of self-leadership has been on the related process referred to as self-management (Manz & Sims, 1980; Marx, 1982).

Although self-management and self-leadership are related concepts, they are distinctly different. Manz and Sims (1980) introduced self-management as a substitute for leadership. They identified specific methods for personal self-control, such as self-observation and self-goal-setting, and argued that these can serve as substitutes for external leadership. Manz (1986) later argued that a more comprehensive and higher level of self-influence exists than the concept of self-management. Whereas self-management concerns regulating one's behavior to reduce discrepancies from externally set standards, self-leadership goes beyond the reduction of discrepancies and addresses the utility of the rationale for the standards themselves (Manz, 1986). The individual self-leader is viewed as the ultimate source of standards that govern his or her behavior, and individuals are seen as capable of not only monitoring their own actions but also of determining which actions and consequent outcomes are most desirable (Neck, Stewart, & Manz, 1995).

Thought Self-Leadership (TSL) emerges from the idea of self-leadership. As Neck and Manz (1992, p. 682) state, "The underlying premise is that people can influence or control their own thoughts through the application of specific cognitive strategies and ultimately impact individual and organizational performance." These cognitive strategies typically include self-talk and mental imagery. The ability of self-

talk and mental imagery to enhance performance has been empirically supported in sports psychology (e.g., Feltz & Landers, 1983; Ievleva & Orlick, 1991), clinical psychology (e.g., Driskill, Cooper, & Moran, 1994), counseling psychology (Kurpius, Benjamin, & Morran, 1985), education (Swanson & Kozleski, 1985), and communication (Boice, 1985).

Similar to the other interventions reviewed and also the error training statements, TSL attempts to influence individuals' self-dialogue and thought patterns. For example, Manz (1992) has identified two competing types of thought patterns that a person can adopt – “opportunity thinking” and “obstacle thinking.” Opportunity thinking involves a pattern of thoughts that focuses on opportunities, worthwhile challenges, and constructive ways of dealing with challenging situations (Neck & Manz, 1992). Obstacle thinking, on the other hand, involves a focus on the negative aspects involved in challenging situations, including reasons to give up and retreat from problems. Research has shown that opportunity thinkers exert more effort and try harder during the course of work (e.g., Seligman, 1991; Neck & Manz, 1996a, 1996b). TSL, therefore, often aims to increase opportunity thinking and focuses on replacing negative self-talk with self-talk of a more constructive and positive nature.

Although empirical research on TSL is limited, research by Neck and Manz (1996a) suggests that this approach may be an effective means of promoting cognitive self-control. In a training intervention-based field study with a control group, Neck and Manz examined the effectiveness of TSL for influencing the thought patterns of individuals in an organization that recently filed for bankruptcy financial status. The training group met for 2 hours each week for 6 weeks. The training sessions focused on

topics such as self-dialogue, mental imagery, thought patterns, and relapse prevention. The results suggested that individuals who received the training experienced increased mental performance, positive affect, job satisfaction, and decreased negative affect relative to those not receiving the training.

Emotion-control in error training. Previous research on error training has typically given individuals in the error-training group a set of four statements. These statements are designed to counter the emotional and frustrating quality of errors and to increase the problem-solving approach to error correction. Typically, the following four statements are used: “I have made an error. Great!,” “There is a way to leave the error situation,” “Look at the screen,” and “I watch what is on the screen and what is changing.” The first two statements are aimed at reducing the emotional impact of errors, whereas the last two are designed to promote error management strategies (Frese et al., 1991). Early studies by Frese and colleagues suggested that novices did not observe the screen very well and, therefore, often did not notice when an error occurred.

Although many studies have used this same set of four statements (e.g., Dormann & Frese, 1994; Nordstrom et al., 1998), research by Irmer et al. (1991) suggests that teaching error management strategies does not contribute anything over a more general error training approach. Thus, it is likely that the last two statements noted above have little impact on individuals’ learning, performance, and affect. In fact, a recent study by Heimbeck et al. (2000) designed to examine the influence of the emotion-control statements did not include statements designed to promote error management strategies. Instead, the study focused only on those statements that attempt to reduce the emotional impact of errors.

Two important questions concerning the statements used in error training remain largely unanswered. First, are the emotion-control statements an important element of error training? As I mentioned earlier, Frese has gone back-and-forth on this issue. In 1991 he argued that the statements have a major impact on individuals' emotions, but then later in 1995 noted that he had been unable to replicate these results and had become weary of the "emotional hypothesis." I believe this confusion stemmed, at least in part, from the fact that Frese's early studies did not compare the effects of error training with and without the statements. Thus, when differences in trainees' level of frustration or anxiety were observed, it was impossible to know whether this was due to the statements or some other element in the training environment.

In an attempt to address this limitation and provide a formal test of the statements, Heimbeck, Frese, and Sonnentag (2000) compared the effects of error training with and without the emotion-control statements. The results revealed that both short- and long-term performance were greater for the group that received the statements. So, this study seems to suggest that the emotion-control statements are indeed an important component of error training. However, several limitations of this study did not allow for an answer to a second important question – what is the process by which the statements impact learning and performance?

Although the statements are designed to reduce the emotional impact of errors, Heimbeck et al. (2000) did not measure trainees' affect. In addition, they found, contrary to their expectations, that the statements did not impact state goal orientation. As a result, the Heimbeck et al. (2000) study does not provide much insight into how the statements in error training operate. An additional limitation was that several of the statements

developed by Heimbeck and colleagues focused heavily on promoting errors (e.g., “The more errors you make, the more you learn!”). This raises questions concerning whether the statements really functioned as an emotion-control intervention, or whether they were simply a way to encourage individuals to make errors. The primary goal of the emotion-control statements is supposed to be to encourage individuals to think rationally about errors when they occur, not to encourage individuals to make errors (Frese, 1995).

I would argue that the statements used in error training promote positive self-talk and, therefore, should have a beneficial impact on individuals’ affect over and above the effects of error encouragement. In Frese et al. (1991), for example, experimenters observed individuals’ performance and when they made an error would say something like “that is good, now you can learn from this error.” This type of statement does not necessarily promote errors, but rather stimulates constructive and positive self-dialogue when errors occur. In self-leadership terms, the statements may get individuals to view the error as an opportunity rather than an obstacle, which may, in turn, increase positive affect, reduce negative affect, and stimulate greater effort and persistence. The emotion-control statements also attempt to promote feelings of control, which creates an emotional advantage over simply encouraging errors. The statement “There is a way to leave the error situation” is designed to let people know that they are in control and they are not trapped in an error state. This is similar to Kanfer and Ackerman’s intervention, which tells individuals to adopt a “Can Do” attitude.

Aptitude x Treatment Interactions

Although the primary focus of the current study was to decompose the various elements of error training and examine the processes by which these elements have their

effects, a secondary aim was to examine the interaction of these elements with several individual difference variables. A number of researchers have suggested that a number of individual differences, such as ability, may determine the relative effectiveness of error training. However, very little empirical research has examined these proposed aptitude X treatment interactions. In the current study, therefore, I performed a series of supplemental analyses to explore a number of the aptitude x treatment interactions that have been suggested in past research. Below, I discuss potential interactions between the three elements of error training and several individual difference variables.

Exploratory learning and individual differences. Research suggests that a number of individual difference variables may determine the relative effectiveness of exploratory learning. Snow (1986), for example, reported that students with lower levels of ability benefit from tightly structured lessons, whereas students with higher levels of ability perform better in less structured, error-filled environments that provide room for independent learning. Similarly, Gully et al. (2002) found that high ability trainees performed better under “make errors” instructions, while low ability trainees performed better under “avoid errors” instructions. It has been argued that low ability trainees do not possess the cognitive resources necessary to make effective use of exploratory learning and errors (Gully et al., 2002). Furthermore, research has shown that both exploratory learning and errors increase trainees’ workload (e.g., Schönplflug, 1985; Tuovinen & Sweller, 1999). Thus, self-guided learning and errors add an additional level of complexity that consumes the already limited cognitive resources of low ability individuals.



Gully et al. (2002) also found that openness to experience moderated the impact of error training on several important training outcomes. Individuals high in openness to experience are more curious, imaginative, and broad-minded (Barrick & Mount, 1991). They also may be more willing to engage in new approaches to learning, which may explain why openness to experience tends to have a positive impact on training proficiency (Barrick & Mount, 1991). Consistent with past research, Gully et al. found that openness to experience was positively related to trainees' self-efficacy, knowledge, and performance. In addition, Gully et al. found that the positive relationship between openness to experience and training outcomes was particularly strong when training encouraged errors, but that these relationships disappeared when errors were discouraged. The authors suggest that these results may be due to the fact that error training encourages exploration and trainees higher in openness are more likely to engage in exploratory behaviors. In other words, it appears there is a particularly good fit between individuals high in openness to experience and the active, exploratory approach of error training. Error avoidant training, however, restricts exploration for trainees high in openness, thereby nullifying the positive effects of openness on training outcomes.

Error encouragement and individual differences. Research suggests that the effects of error encouragement and error avoidance may also differ depending on several individual difference variables. Gully et al. (2002), for example, found that conscientiousness interacted with the type of error instructions to influence individuals' self-efficacy. The nature of this interaction was such that individuals high in conscientiousness had higher levels of self-efficacy when they were encouraged to avoid errors, whereas individuals low in conscientiousness had higher levels of self-efficacy

when encouraged to make errors. This finding is consistent with the fact that individuals high in conscientiousness tend to be careful, thorough, responsible, organized, achievement-oriented, and hardworking (Barrick & Mount, 1991; Martocchio & Judge, 1997). In fact, one of the dimensions of conscientiousness is cautiousness (Costa & McCrae, 1992; Hogan & Ones, 1997), which has been measured by the extent to which individuals avoid mistakes (Goldberg, 1999). Thus, Gully et al. (2002) suggest that error encouragement may have negative effects for individuals high in conscientiousness because making mistakes is inconsistent with their natural disposition.

Emotion-control and individual differences. Kanfer and Ackerman (1990) found that their emotion-control intervention benefited low ability trainees, but not high ability trainees. There are several potential explanations for this finding. First, low ability individuals are more likely to make errors and experience poor performance, which, in turn, produces negative emotions, such as stress and anxiety. As a result, strong emotion-control skills may be particularly important for low ability individuals because they are more prone to experience negative emotions. Second, a number of researchers (e.g., Kanfer & Ackerman, 1990; Reason, 1990; Wood et al., 2000) have argued that emotions, such as stress and anxiety, increase cognitive load and divert attentional resources away from the task at hand. Whereas high ability individuals may have enough cognitive resources to split between performing a task and monitoring their emotions, low ability individuals have more limited cognitive resources. As a result, any diversion of their resources away from the task probably has a significant and negative impact on their performance. Overall, the emotion-control benefits of the error training heuristics should be greater for low ability individuals because of their increased susceptibility to negative

emotions and the significant impact that any type of distraction will have on their performance.

Although up to this point we have been focusing on state anxiety and its effects, research has also shown that individuals differ in terms of their natural, or trait, level of anxiety (e.g., Gaudry, Vagg, & Spielberger, 1975; Spielberger, 1985). Whereas some individuals are relatively immune to anxiety and stress, other individuals are prone to such emotions. Put simply, some individuals are more likely than others to experience high levels of state anxiety. These differences in trait anxiety, therefore, may play an important role in determining the impact of an emotion-control intervention. Individuals who are anxiety prone are more likely to react negatively to events, such as errors, and be distracted by the worry and anxiety that accompanies them. In contrast, individuals who have relatively low levels of trait anxiety will be less likely to develop anxiety and, therefore, be distracted by their emotions. As a result, the emotion-control statements included in error training should be especially important for individuals high in trait anxiety, because of their enhanced susceptibility to state anxiety.

HYPOTHESES

In this section, I present the hypotheses that were tested in the current study. These hypotheses are based on the literature review just presented and are represented by the conceptual model presented in Figure 1. As can be seen in Figure 1, the current study decomposed the instructional, motivational, and emotional elements of error training described above. This decomposition allows for a direct test of the impact that each of these elements has on learning and performance. In addition, the present research examined the process by which these three elements exert their effects on learning and performance. Each of the elements of error training was expected to influence a number of process variables, which, in turn, were expected to impact learning and performance. Examining the instructional, motivational, and emotional elements of error training and the means by which these elements impact learning and performance represented the primary focus of the current study.

Although not represented in Figure 1, the current study also explored interactions among the elements of error training and between these elements and several relevant individual difference variables. Because past research has failed to decompose the various elements of error training, these treatment and treatment x aptitude interactions have typically not been examined in previous studies. However, as discussed in the literature review, there is good reason to believe that the effects of the various elements of error training depend both on the characteristics of trainees. Exploring these various interactions represented a secondary or supplementary goal of the current study.

In the following sections, I explicate the rationale for the hypotheses that were examined in the current study. First, I outline the expected effects of the instructional



element (exploratory learning vs. proceduralized instruction) of error training. Then, I discuss the potential impact of the motivational element (make vs. avoid errors instructions) of error training. This is followed by predictions concerning the emotional element (emotion-control vs. no emotion-control) of error training. In each of these sections, I also briefly describe the expected impact of the process variables. The impact of these process variables on learning and performance has been examined rather extensively by previous research, so these effects were not the core focus of the current study. However, they are important to the extent that they explain the effects of the different elements of error training. After I have outlined the independent effects of the three elements of error training, I discuss potential interactions between these elements and several individual difference variables.

Instructional Element of Error Training

The instructional element of error training involves the nature of instruction that trainees receive. As described earlier, error training provides individuals with an unstructured or exploratory learning environment, which is designed to prompt errors and create an active learning style. In past research, this exploratory approach to learning has been operationalized by providing individuals with basic task instructions and commands, but very little additional guidance. In contrast, individuals in the comparison group are typically provide traditional, proceduralized instruction, which is operationalized by giving individuals detailed, step-by-step instructions and all the commands necessary to perform the task (e.g., Dormann & Frese, 1994; Frese et al., 1988; Nordstrom et al., 1998). To maintain consistency with previous research, similar instructional manipulations were used in the current study – one group of trainees

received exploratory learning conditions and the other group of trainees were given proceduralized instruction (see Smith, 1996, for similar manipulations). The hypotheses below examine the effects of these different types of instruction.

Near transfer performance. Numerous studies have compared the effects of exploratory learning and proceduralized instruction on near transfer (e.g., training) performance. In general, this research suggests that exploratory learning and proceduralized instruction produce similar levels of near transfer performance (e.g., Dormann & Frese, 1994; Frese et al., 1991; McDaniel & Schlager, 1990; Smith, 1996). In other words, these two techniques appear to be equally effective for developing reproducible skills and promoting performance in situations analogous to the training environment.

However, research also suggests that the effects of exploratory learning on performance may depend on the complexity of the task being trained. Clark and Voogel (1985), for example, argue that more basic, procedural tasks are well suited for training by errorless learning and other traditionally behaviorist techniques, whereas more cognitively-based and complex tasks that require conceptual knowledge and the development of mental models are better suited to exploratory learning. Similarly, Heimbeck et al. (2000) suggest that error training and its exploratory learning approach may be more beneficial for complex tasks because such tasks involve a greater number of errors and require deeper levels of knowledge and skill. Empirical research has provided some support these arguments. Both Dormann & Frese (1994) and Frese et al. (1991) found that while exploratory learning and proceduralized instruction produced similar levels of performance on basic task components, the exploratory learning group exhibited

superior performance on more difficult or complex aspects of the task. In the current study, therefore, I predict that exploratory learning and proceduralized instruction lead to similar levels of basic performance in near transfer, but exploratory learning will lead to significantly higher levels of strategic performance in near transfer.

Hypothesis 1: Exploratory learning and proceduralized instruction produce similar levels of basic performance in near transfer. However, exploratory learning leads to significantly higher levels of strategic performance in near transfer.

Knowledge. Theoretical work suggests that exploratory learning may lead to greater levels of knowledge than proceduralized instruction. Since individuals must develop a solution to the task on their own, the knowledge they acquire through exploratory learning becomes better integrated into their existing knowledge (Egan & Greeno, 1973; Frese et al., 1988). The more individuals are able to integrate new information into their existing conceptualizations of a knowledge domain, the better they are able to learn (Frese et al., 1988; Volpert, 1987). In addition, exploratory learning allows individuals to make errors and, therefore, individuals learn from not only performing the task correctly but also from making mistakes (Ivancic & Hesketh, 1995/1996, Singer & Pease, 1976). These mistakes facilitate the development of a better operative mental model of the task because individuals can incorporate potential pitfalls and error-prone areas (Frese, 1995). Furthermore, exploration exposes individuals to a wider range of task material and, therefore, expands the breadth of their knowledge.

Consistent with these theoretical arguments, empirical research has shown that exploratory learning often leads to increased knowledge. Frese et al. (1988), for

example, found that individuals in an exploratory learning condition had greater recall of task commands than individuals who received proceduralized instruction. Similarly, Kamouri et al. (1986) found that exploratory learning enhanced recall of the operation of three training devices encountered two days earlier. Although past research has not examined the effectiveness of exploratory learning for developing different types of knowledge, I would argue that an active, exploratory approach to learning should be particularly beneficial for developing more complex and strategic knowledge. This is supported by work that has shown that exploratory learning enhances the development of strategies (McDaniel & Schlager, 1990).

Hypothesis 2: Exploratory learning leads to greater task knowledge than proceduralized instruction. This difference is greatest for complex and strategic task knowledge.

Far transfer performance. Undoubtedly, the greatest advantage of exploratory learning lies in its ability to promote the development of generalizable skills. Exploratory learning promotes active processing and mindfulness that leads to the acquisition of knowledge at a higher level of regulation (Frese & Zapf, 1994). In addition, the errors that occur in exploratory learning serve a surprise function and research suggests that surprise induces mindfulness (Salomon & Globerson, 1987). This mindful processing creates abstract representations of a task that provide a bridge from one context to another, thereby facilitating far transfer (Salomon & Perkins, 1989). In contrast, proceduralized instruction is often based on a very concrete representation of problem-solving actions, which may encourage individuals to represent the problem domain at an inappropriate level of abstraction and, therefore, inhibit far transfer (Carlson et al., 1992;

Simons & DeJong, 1992). Numerous studies have empirically demonstrated the superiority of exploratory learning for developing generalizable skills (e.g., Frese et al., 1988; Hermann, 1969; Ivancic & Hesketh, in press; Kamouri et al., 1986; McDaniel & Schlager, 1990). Thus, I predict that in the current study exploratory learning will lead to greater far transfer or generalization performance than proceduralized instruction. Once again, however, I suggest that exploratory learning will be particularly effective for promoting the generalization of more complex and strategic skills.

Hypothesis 3: Exploratory learning leads to greater generalization or far transfer performance than proceduralized instruction. This difference is most pronounced on more complex and strategic aspects of the transfer task.

Hypothesis-testing. While it is important to examine the overall effects of exploratory learning, it is equally as important to understand the process by which exploratory learning has its effects on learning and performance. One mechanism that may be important is hypothesis testing. Research suggests that exploratory learning facilitates the use of hypothesis-testing and problem-solving skills (Ivancic & Hesketh, 1995/1996). As individuals explore a task, they typically do not engage in blind trial-and-error. Instead, exploration is typically based on hypotheses and is guided by some kind of mental model (Carroll et al., 1985; Grief & Keller, 1990). In contrast, proceduralized instruction restricts the use of hypothesis-testing and problem-solving skills. Since individuals are given step-by-step instructions and correct problem solutions, there is no need to use hypothesis-testing or problem-solving skills to discover appropriate solutions. Smith (1996), for example, found that discovery learning led to greater hypothesis-testing than proceduralized instruction. Similarly, Pfeffer (1992)

found that individuals given proceduralized instruction used exploration in a trial-and-error sense, whereas individuals who received error training used exploration in a more hypothesis-driven manner.

Hypothesis 4a: Exploratory learning leads to greater use of hypothesis-testing skills than proceduralized instruction.

As individuals test their hypotheses, they increase their understanding of the relational structure of the domain and revise their mental model (Rasmussen, 1990). Hypothesis testing may also facilitate the search for new information and allow individuals to learn about aspects of the task they otherwise would not have been exposed to. Smith (1996), for instance, found that hypothesis-testing was significantly and positively related to verbal knowledge. In addition, research has shown that “eliminative” tests that show a particular solution is wrong are very helpful for discovering the correct solution (Klayman & Ha, 1989). And, McDaniel and Schlager (1990) suggest that individuals who use hypothesis-testing approaches during training will develop a greater repertoire of task strategies; they will test a greater number and diversity of task strategies. Thus, hypothesis testing should be positively related to both knowledge and performance.

Hypothesis 4b: Hypothesis-testing is positively related to knowledge and performance.

Metacognitive activity. Because most major learning decisions are made for trainees, traditional training programs tend to be passive in nature. For example, proceduralized instruction clearly specifies the content trainees should study and practice and provides step-by-step guidance on how to perform the task. In exploratory learning,

however, control over major learning decisions is shifted to the trainee. It has been argued that this control serves to engage individuals' metacognitive processes (Smith et al., 1997). These metacognitive processes are distinct from hypothesis testing and refer to an awareness of cognitive processes and the monitoring of errors and task strategies (Eteläpelto, 1993; Flavell, 1979). Metacognition includes planning, monitoring, and revising goal appropriate behavior (Brown, Bransford, Ferrara, & Campione, 1983). For example, in exploratory learning an individual must judge his or her progress, determine what content to study and practice, and evaluate task strategies and problem solutions. In addition, since exploratory learning involves errors, individuals must diagnose their mistakes and determine the most effective means of improving their performance. Thus, I predict that exploratory learning will lead to greater metacognitive activity than proceduralized instruction.

Hypothesis 5a: Exploratory learning leads to greater metacognitive activity than proceduralized instruction.

Individuals who exhibit greater metacognitive activity are expected to learn and perform more effectively because they monitor their progress, determine when they are having problems, and adjust their learning accordingly (Ford et al., 1998). Several studies have found relationships between metacognitive activities and achievement outcomes. Eteläpelto (1993), for example, found that expert computer programmers were superior to novice programmers in their metacognitive knowledge of a programming task and working strategies. In addition, experts engaged in greater cognitive monitoring and had more adequate task-specific awareness. Pintrich and DeGroot (1990) found that individuals' self-reported assessments of self-regulated learning were positively related to

academic performance. Finally, Ford et al. (1998) found that metacognition was positively related to both knowledge and performance on a task similar to the one used in the current study.

Hypothesis 5b: Metacognitive activity is positively related to both knowledge and performance.

Cognitive effort. In comparison to proceduralized instruction, exploratory learning may increase the amount of attention individuals devote to a task. In part, this may be due to the fact that exploratory learning increases the number of errors that occur during learning (Ivancic & Hesketh, 1995/1996). Errors not only serve a surprise function that attracts individuals' attention, but cognitive resources are also required to diagnosis and recover from errors (Schönplflug, 1985). Exploratory learning may also require greater cognitive attention than proceduralized instruction because more effort is required to solve problems (Ivancic & Hesketh, 1995/1996). In many ways, cognitive effort serves as a surrogate for the effortful processing that is viewed as critical in the development of adaptive expertise. Tuovinen & Sweller (1999) compared the mental effort involved in using exploration or worked-examples practice to learn a database program. They found that exploratory learning required significantly higher levels of mental effort than worked-examples practice, especially for individuals with no previous domain familiarity. Based on these findings, I argue that exploratory learning will lead to higher levels of cognitive effort than proceduralized instruction.

Hypothesis 6a: Exploratory learning leads to significantly higher levels of cognitive effort than proceduralized instruction.

Although extremely high levels of cognitive burden can certainly be detrimental to learning and performance, moderate increases in cognitive effort can actually be beneficial. Increased cognitive attention can produce a shift from automatic processing to effortful controlled processing (Frese et al., 1988; Frese & Altmann, 1989; VanLehn, 1991). Increased time spent practicing a skill using controlled processing can foster schema extraction and the learning of principles (Sweller, 1988) and prevent the premature automatization of a skill (Frese, 1995; Frese & Zapf, 1994). In addition, several models of learning have emphasized the ability of surprising or unusual stimuli to generate learning, presumably because such events attract individuals' attention (e.g., Holyoak et al., 1989). Consistent with these arguments, Fisher (1995) found a positive relationship between cognitive effort and knowledge and performance.

Hypothesis 6b: Cognitive effort is positively related to knowledge and performance.

Intrinsic motivation. The final mechanism by which exploratory learning may impact learning and performance is motivational in nature. It has been argued that individuals in an exploratory learning setting may be more intrinsically motivated because they have control over their learning (Singer & Pease, 1976). Indeed, Deci and Ryan's self-determination theory (Deci & Ryan, 1985; Ryan, Kuhl, & Deci, 1997) argues that intrinsic motivation is increased by feelings of autonomy, and empirical work has supported this argument (Deci, Koestner, & Ryan, 1999; Reeve, 1996). Exploratory learning is also more challenging and engaging, which may enhance intrinsic motivation by increasing individuals' feelings of competence (Deci, 1975; Vallerand & Reid, 1984). In proceduralized instruction, however, individuals are engaged in a passive learning

process and simply practice the application of procedures. The external control inherent in proceduralized instruction may be perceived by trainees as a constraint, which may, in turn, reduce intrinsic motivation (Deci, 1971). A study by Nordstrom et al. (1998) found that error training increased intrinsic motivation, and Frese (1995) argues that observations from their studies suggest that individuals given error training are often more motivated. Although I believe this motivational benefit is derived primarily from the nature of the error encouragement instructions provided in error training, the active, exploratory nature of error training may also have a significant, albeit smaller, impact on intrinsic motivation.

Hypothesis 7a: Exploratory learning leads to greater intrinsic motivation than proceduralized instruction.

Intrinsic motivation has been shown to be positively related to interest, excitement, and confidence, which in turn lead to improved outcomes, such as higher performance, greater persistence, and creativity (Deci & Ryan, 1991; Sheldon, Ryan, Rawsthorne, & Ilardi, 1997). In addition, individuals tend to exhibit more positive outcomes when their actions are intrinsically motivated than when they are externally regulated, for example by rewards or demands (Ryan & Deci, 2000). The benefits of internalization have been found in numerous areas of inquiry, including education (e.g., Miserandino, 1996), healthcare (e.g., Williams, Rodin, Ryan, Grolnick, & Deci, 1998), and intimate relationships (Blais, Sabourin, Boucher, & Vallerand, 1990). Thus, I hypothesize that greater intrinsic motivation will lead to greater knowledge and performance.

Hypothesis 7b: Intrinsic motivation is positively related to knowledge and performance.

Motivational Element of Error Training

The second critical element of error training is motivational in nature and involves the instructions that trainees are given. Traditional training programs tend to follow principles derived from the behaviorist tradition and, as a result, view errors as negative events. The goal of such programs is to eliminate errors from training; therefore, trainees are discouraged from making errors. In error training, however, errors are viewed as an important part of the learning process. In addition, a fundamental premise of error training is that errors only reduce motivation when they are viewed as negative occurrences. Therefore, error training attempts to frame errors in positive terms by encouraging trainees to make mistakes. A goal of the current study was to examine the motivational implications of these error encouragement and error avoidance instructions. Below, I present the hypotheses that focus on the effects of these different types of instructions.

Near transfer performance. Earlier I suggested that error encouragement is likely to stimulate a learning orientation, whereas error avoidance is likely to create a performance-avoid orientation. Indeed, a number of studies have used error encouragement instructions to create a learning environment and error avoidance instructions to create a performance environment (e.g., Kozlowski, Gully, Smith, Nason, & Brown, 1995; Nordstrom et al., 1998). Research suggests that goal orientation has important implications for performance. For example, Colquitt & Simmering (1998) found that individuals with higher levels of learning orientation had a higher motivation

to learn, which in turn led to increased performance. Overall, research has shown that contexts that stimulate a learning orientation tend to lead to higher levels of performance than those that lead to a performance orientation (e.g., Bell et al., 1999; Cannon-Bowers, Rhodenizer, Salas, & Bowers, 1998; Kozlowski et al., 1995; Kozlowski et al., 2001; Nordstrom et al., 1998; Stevens & Gist, 1997). Thus, I predict that error encouragement will lead to higher levels of basic and strategic performance in near transfer than error avoidance.

Hypothesis 8: Error encouragement leads to higher levels of basic and strategic performance in near transfer than error avoidance.

Knowledge. Error encouragement and error avoidance may also impact the effort that individuals focus on learning a task. When individuals are encouraged to avoid errors, they will focus greater effort on performing well than on learning the task. They will focus on superficial aspects of the task that lead directly to performance, and avoid learning complex strategies and principles embedded in the task (Kozlowski et al., 2001). In addition, research in the area of goal orientation suggests that individuals who are focused on avoiding errors are more likely to withdraw from a task in the face of failure. This task withdraw may limit the extent to which individuals acquire important task knowledge. Avoid error instructions may also make the task less interesting and fun, which may hurt learning. Error encouragement, on the other hand, reframes errors as learning opportunities and as challenges, which shifts trainees' focus from performance to learning. Individuals encouraged to make errors may be more likely to explore complex relations in the task, because they are more willing to accept the errors involved in exploration. In addition, when individuals are encouraged to make errors, they may

view errors as an opportunity to learn and use the experiences to revise their mental model of the system. Finally, error encouragement may increase intrinsic motivation, which, in turn, may enhance learning. Overall, instructions that encourage trainees to make errors should lead to greater knowledge than instructions that encourage trainees to avoid errors.

Hypothesis 9: Error encouragement instructions lead to greater basic and strategic knowledge than error avoidance instructions.

Far transfer performance. The positive effects of error encouragement on learning and performance during training should translate into greater far transfer or generalization performance. For example, individuals who are encouraged to make errors will devote greater effort to learning the task. As a result, they will develop a more accurate and complete mental model of the system that they can transfer to more difficult and complex task situations. In addition, the learning orientation that is stimulated by error encouragement may serve to bolster individuals' self-efficacy. Research suggests that self-efficacy has a positive effect on adaptive performance (Ford et al., 1998; Kozlowski et al., 2001). Individuals who are encouraged to avoid errors, however, will have a more superficial understanding of the task. They most likely will avoid the difficult or complex aspects of the task during training, because doing so involves less effort and reduces the chances of making mistakes. Thus, these individuals will be poorly equipped to face the challenges of a more difficult and complex task situation. In addition, the performance oriented nature of error avoidance may reduce individuals' self-efficacy, which may subsequently hurt far transfer performance.

Hypothesis 10: Error encouragement instructions lead to greater basic and strategic performance in far transfer than error avoidance instructions.

State goal orientation. So, how do different types of error instructions influence learning and performance? In the literature review presented above, I discussed how error encouragement stimulates a learning orientation and error avoidance creates a performance-avoid orientation. I believe that the effects of error instructions on learning and performance occur through the effects that these instructions have on individuals' goal orientation. In other words, I suggest that the effects of error encouragement and error avoidance are mediated by their effects on individuals' state goal orientation.

Although goal orientation was originally characterized as a trait-like variable, research has shown that it can be influenced by situational factors, such as goals (Kozlowski, Gully, Smith, Brown, Mullins, & Williams, 1996). As Kraiger et al. (1993, p. 320) state, "Although the performance and mastery orientation was originally conceived of as an individual difference variable, more recent research has characterized it as a general motivational tendency that is adaptable to situations or interventions." When trainees are encouraged to avoid errors, their primary focus is on errorless performance. Their attention is directed to performing well and avoiding errors rather than acquiring a deep understanding of the task. In addition, they are more likely to view errors as an indication of low ability, which is characteristic of a performance orientation. Error encouragement, on the other hand, shifts trainees' focus from performance to learning. Errors are viewed as opportunities to learn rather than as indications of low ability. Indeed, past research on mastery training has often used error encouragement to promote a mastery or learning orientation (e.g., Kozlowski et al., 1995). Thus, I argue

that error encouragement will create a state learning orientation and error avoidance will stimulate a state performance-avoid orientation.

As discussed earlier, how these error instructions influence state performance-prove orientation is difficult to predict. Error encouragement and error avoidance directions best represent a distinction between learning orientation and performance-avoid orientation. Therefore, it may be that neither of these directions has an impact on individuals' performance-prove orientation. At the same time, error encouragement is clearly more approach oriented than error avoidance. Thus, it may be that error encouragement has a positive effect and error avoidance a negative effect on trainees' state performance-prove orientation. Rather than choosing between these competing hypotheses, the data from the current study will be used to explore these alternatives.

Hypothesis 11: Error encouragement has a positive effect on learning orientation and a negative effect on performance-avoid orientation. Error avoidance has a negative effect on learning orientation and a positive effect on performance orientation. The effects of these instructions on performance-prove orientation will be examined in a more exploratory manner.

Effects of state goal orientation. Numerous studies have revealed a significant relationship between goal orientation and knowledge and performance. In general, this research has found that learning orientation has a positive relationship and performance orientation a negative or null relationship with learning and performance (e.g., Button et al., 1996; Fisher & Ford, 1998; VandeWalle et al., 1999). Furthermore, it appears that the performance-avoid orientation has rather consistent negative effects on knowledge and performance, while performance-prove orientation has displayed both null and

positive relationships with different outcomes (e.g., VandeWalle, Cron, & Slocum, 2001). Although much of this research has focused on the effects of trait goal orientation, there is evidence to suggest that state goal orientation is likely to have effects similar to its trait counterpart (e.g., Bell et al., 1999; Bell, Kozlowski, & Dobbins, 2001). Additionally, research suggests that the relationships between goal orientation and learning and performance tend to be mediated by several variables. In the current study, I examined three variables, intrinsic motivation, self-efficacy, and anxiety, that past research suggests are important mediators of the effects of goal orientation on learning and performance. In addition, these three variables have been discussed as important in past research on error training, although their mediating role has rarely been examined. Below I discuss the effects of state goal orientation on these three variables.

Intrinsic motivation. When individuals adopt a performance-avoid orientation they are focused on avoiding errors. Under these conditions, errors may be viewed as punishment and individuals' actions are regulated around externally imposed performance standards (e.g., errorless performance). These factors may reduce individuals' intrinsic motivation (Deci, 1971). In contrast, individuals with a learning orientation view errors as positive and challenging events. In addition, individuals who are learning oriented may feel they have greater control over their learning because they set their own standards of performance. Thus, learning orientation should be positively related to intrinsic motivation. Indeed, a study by Nordstrom et al. (1998) found that trainees given learning goals had higher levels of intrinsic motivation than trainees given performance goals. The effects of performance-prove orientation on intrinsic motivation

are less clear. However, when individuals are striving to do well rather than avoid errors, they should be more likely to experience higher levels of intrinsic motivation.

Hypothesis 12: State learning orientation and performance-prove orientation are positively related to intrinsic motivation, and state performance-avoid orientation is negatively related to intrinsic motivation.

Self-efficacy. Research suggests that self-efficacy is also an important mediator of goal orientation-outcome relationships. Self-efficacy can be defined as a personal judgment of “how well one can execute courses of action required to deal with prospective situations” (Bandura, 1982, p. 122). In part, the influence of goal orientation on self-efficacy might stem from how individuals with different levels of learning, performance-avoid, and performance-prove orientation view errors and task failure. Individuals with a performance-avoid orientation are more likely to view errors as negative events and as something to avoid. As a result, individuals with a performance-avoid orientation are more likely to interpret errors as an indication of low ability, which may hurt their self-efficacy. In contrast, individuals with a learning orientation view errors as challenging events and as an integral part of the learning process. As a result, learning oriented individuals may interpret errors as an opportunity to increase their ability, which may bolster their self-efficacy (Henderson, 1986). At a minimum, learning oriented individuals should be more immune from the negative effects of errors (Button et al., 1996). Consistent with these arguments, research has shown that learning oriented individuals tend to exhibit higher levels of self-efficacy than performance oriented individuals (e.g., Button et al., 1996; Ford et al., 1998; Phillips & Gully, 1997). Individuals with high levels of performance-prove orientation, however, are not likely to

view errors strictly as something to avoid or as something to use as a learning experience. Instead, they may view errors as obstacles to demonstrating their competence but not as strong negative or positive events. Consistent with this reasoning, VandeWalle and colleagues (2001) found that performance-prove orientation did not display a significant relationship with self-efficacy. Thus, I predict that learning orientation will be positively related to self-efficacy, performance-avoid orientation negatively related to self-efficacy, and performance-prove orientation unrelated to self-efficacy.

Hypothesis 13a: State learning orientation is positively related to self-efficacy, state performance orientation is negatively related to self-efficacy, and state performance-prove orientation unrelated to self-efficacy.

Bandura (1986, 1997) argued that individuals who perceive themselves as highly efficacious will activate sufficient effort that, if well executed, will produce successful outcomes, whereas those who perceive low self-efficacy will withdraw their efforts prematurely and fail on the task. Several meta-analyses have supported this argument and have revealed a strong, positive relationship between self-efficacy and task performance (Chen, Casper, & Cortina, 2000; Multon, Brown, & Lent, 1991; Sadri & Robertson, 1993; Stojkovic & Luthans, 1998).

Hypothesis 13b: Self-efficacy is positively related to basic and strategic training performance.

State anxiety. The final variable that will be examined as a mediator of goal orientation-outcome relationships is state anxiety. Researchers have found that learning goal orientation is negatively related, whereas performance goal orientation is positively related, to state anxiety (Chen, Gully, Whiteman, & Kilcullen, 2000; Pintrich, Smith,

Garcia, & McKeachie, 1993; Roedel, Schraw, & Plake, 1994). As discussed earlier, anxiety occurs when a person makes a cognitive appraisal that a substantial imbalance exists between perceived environmental demands and perceived response capability. Individuals with a performance-avoid orientation may perceive errorless performance to be an extremely difficult or impossible goal, which is likely to increase their anxiety. In addition, any errors they make are likely to increase the perceived imbalance between the goal and their current ability and, in turn, increase their anxiety. However, when individuals adopt a learning orientation, performance pressures are reduced considerably. In addition, errors are viewed in positive terms and, therefore, may not lead to negative perceptions of ability. Once again, the impact of performance-prove orientation on state anxiety is difficult to ascertain. However, since individuals with a performance-prove orientation are neither striving to avoid incompetence nor striving to simply learn, it is likely that the competing motives of need for achievement and fear of failure will balance out to create a negligible relationship between state performance-prove orientation and state anxiety.

Hypothesis 14a: State learning orientation is negatively related to state anxiety, state performance-avoid orientation is positively related to state anxiety, and state performance-prove orientation is unrelated to state anxiety.

Anxiety is typically viewed as having a negative relationship with learning and performance. This relationship is generally viewed from a cognitive resource perspective. Researchers have argued that anxiety is detrimental because it diverts attentional resources away from on-task activities (e.g., Kanfer & Ackerman, 1990; Kanfer et al., 1996; Mikulincer, 1989; Wood et al., 2000). When individuals become

distracted by worry and anxiety, the resources they are able to devote to learning and performance are limited. A number of studies have shown that state anxiety results in limited information processing capacity, decreased sensitivity to informational cues, and confused patterns of decision making (Catell & Schier, 1961; Spielberger, 1966).

Hypothesis 14b: State anxiety is negatively related to basic and strategic knowledge and performance.

Emotional Element of Error Training

The third and final element of error training involves the emotion-control statements that are aimed at influencing individuals' emotions surrounding errors. Errors can produce several negative emotional reactions in individuals, namely frustration and anxiety. As a result, training that purposely increases the number of errors that trainees make must also attempt to control the emotions that are associated with errors. Past research on error training, therefore, has included statements that are designed to get people to think rationally about errors. These statements are typically framed in the first-person so that people incorporate them into their thought patterns. For example, typically when a trainee makes an error he or she may think, "I made an error. I am stupid and will never learn this material." Error training, however, uses statements such as, "I made an error. Great!" to counter individuals' negative thoughts. The goal is to substitute positive, constructive thoughts in the place of what are normally negative, counterproductive thoughts concerning errors. The statements are not important so much because of their content, but rather the fact that individuals are substituting positive thoughts for potentially negative ones.

It has been argued that the emotion-control statements are an important component of error training and help to reduce the anxiety and frustration that typically accompany errors (e.g., Heimbeck et al., 2000). However, past research has not focused much attention on examining the independent effect of these statements. As a result, we currently do not know (1) whether the statements are critical for the effectiveness of error training and (2) how they operate if effective. The current study, therefore, attempted to distinguish the effects of the statements from the other elements of error training. Half of the trainees were given emotion-control statements and half were not. The statements focused on promoting rational thought surrounding errors and feelings of personal control, rather than encouraging trainees to make errors. This way the impact of the emotional and motivational elements of error training on individuals' affect remained distinct. Also, the current study examined state anxiety and feelings of control as potential variables that explain the effects of the emotion-control heuristics. Below, I present the hypotheses regarding the emotional element of error training.

Near and far transfer performance and knowledge. As discussed above, anxiety has been shown to have a negative impact on performance. It is believed that these negative performance effects are due to the fact that anxiety diverts attentional resources away from on-task activities (Kanfer & Ackerman, 1990; Kanfer & Heggestad, 1999; Kanfer et al., 1994). Thus, an intervention that reduces anxiety should increase the resources that individuals have available for on-task activities and, subsequently, increase knowledge and performance. In the only study that has directly examined the impact of the emotion-control statements in the context of error training, Heimbeck et al. (2000) found that individuals who received the statements had greater short-term and long-term

performance. Related research on Rational Attitude Training and Thought Self-Leadership also provide indirect evidence that the statements may increase knowledge and performance. This research suggests that providing individuals with positive statements designed to help them control their irrational, non-productive thoughts reduces anxiety and increases knowledge and performance (Neck & Manz, 1996a; Swanson & Kozleski, 1985; Van Raalte et al., 1995). Finally, research by Kanfer and Ackerman (1990) found that encouraging individuals to maintain a positive attitude during training increased performance for low ability trainees.

Thus, I suggest that the statements will have a positive effect on trainees' knowledge and performance. I have chosen to group these hypotheses together here because I believe that the argument presented above will apply uniformly to individuals' near transfer performance, far transfer performance, and knowledge. Essentially, if the heuristics serve to decrease individuals' anxiety, then individuals should have greater cognitive resources available to apply to the on-task activities of learning and performance.

Hypothesis 15: The emotion-control statements lead to greater basic and strategic performance in near transfer.

Hypothesis 16: The emotion-control statements lead to greater basic and strategic knowledge.

Hypothesis 17: The emotion-control statements lead to greater basic and strategic performance in far transfer.

State anxiety. State anxiety is expected to serve as the primary mechanism by which the statements exert their effects on knowledge and performance. Indeed, the

primary aim of the statements is to reduce individuals' anxiety surrounding errors and, in doing so, eliminate the negative effects associated with anxiety. When individuals focus on the negative aspects of challenging situations or engage in other irrational and counterproductive thoughts, they are more likely to perceive an imbalance between environmental demands and their current response capability. In contrast, when individuals engage in opportunity thinking and their thought patterns involve positive and constructive statements, they are more likely to feel as though they can respond to the demands of the situation. These differences in perceived response capability have been shown to have important effects on individuals' anxiety.

Although research in the area of error training has not measured the impact of the statements on anxiety, research on related emotion-control strategies suggests that interventions designed to impact individuals' self-dialogue and rational thinking suggest that such statements can have a significant impact on state anxiety. Research on RAT, for example, has shown that having individuals recite rational statements can help reduce anxiety (Cramer & Kupshik, 1993; Rosin & Nelson, 1983). Similarly, Bloom (1985) suggests that trainees taught to replace worrisome statements with rational ones will exhibit improved emotional control. Kanfer and Ackerman (1990) also found that trainees encouraged to adopt a positive attitude reported fewer negative affective reactions. Finally, Neck and Manz (1996a) found that TSL, which aims primarily to influence individuals' self-dialogue, increased individuals' positive affect and reduced their negative affect. Based on these findings, I argue that participants who receive the heuristics will report less state anxiety than participants who do not receive the heuristics.

Hypothesis 18: *Individuals given the emotion-control statements exhibit less state anxiety than individuals who are not given the statements.*

Personal control. Although I predict that the statements will have a direct effect on individuals' state anxiety, I also believe that this effect may be partially mediated by the effect that the statements have on individuals' perceptions of personal control. Past studies on error training have included statements designed to not only stimulate rational thought but also to facilitate feelings of internal control. A major risk in having individuals make errors is that they will get trapped in an error state, feel helpless, and withdraw from the task. As a result, error training has incorporated emotion-control statements, such as "there is a way to leave the error situation," to minimize individuals' feelings of helplessness and increase their perceptions of control. Kanfer and Ackerman's (1990) emotion-control intervention incorporates a similar strategy and explicitly instructs individuals to adopt a "can do" attitude. Thus, I predict that individuals who are given the statements will have greater feelings of personal control than individuals not given the statements.

Hypothesis 19a: *Participants given the emotion-control statements report greater feelings of personal control than individuals not given the statements.*

Research has shown that causal attributions can have a significant impact on individuals' level of anxiety. More specifically, individuals who perceive greater personal control over their current situation tend to experience lower levels of anxiety. This relates to the fact that individuals who perceive that they can respond to environmental demands tend to experience less anxiety. DuCette & Wolk (1973), for example, found that individuals with a more internal locus of control were more likely to

believe they could meet situational demands and, therefore, experienced less anxiety than individuals with a more external locus of control. Thus, I argue that individuals' perceptions of personal control over their performance will be negatively related to their state anxiety.

Hypothesis 19b: Individuals' perceptions of personal control over their performance is negatively related to their state anxiety.

Treatment and Aptitude x Treatment Interactions

The primary goal of the current study was to examine the relationships outlined above; however, a secondary aim was to examine interactions among the elements of error training and between these elements and several individual difference variables. Past research has suggested that the effectiveness of error training may depend both on the nature of the training environment and on characteristics of trainees; however, many of these potential interactions have not been empirically examined. Others, such as those examined in the Gully et al. (2002) study, need to be reexamined in a context that more cleanly distinguishes the various elements of error training. In this section, therefore, I explore several potential interactions among the three elements of error training and between these elements and several individual difference variables.

Instructional element x motivational element. Past research has always combined the instructional and motivational elements of error training. As a result, exploratory learning has always been supplemented by error encouragement and proceduralized instruction has always been combined with error avoidance instructions. In the current study, however, these elements were examined independently, which creates situations in which the nature of instruction may be at odds with the error instructions that trainees are

given. I believe that the congruence between the instructional and motivational elements of error training will have an impact on trainees' knowledge and performance.

More specifically, I believe that the impact of different types of error instructions will be more pronounced for individuals receiving exploratory learning than for those receiving proceduralized instruction. The combination of exploratory learning and error encouragement should serve to bolster individuals' intrinsic motivation and also increase the extent to which individuals engage in hypothesis-testing and other exploratory activities. Error avoidance, however, will probably minimize the benefits of exploratory learning. If told to avoid errors, individuals may restrict their exploration and be less intrinsically motivated. In addition, since exploratory learning increases the number of errors trainees will make, error avoidance instructions should have a particularly negative effect on individuals' self-efficacy and state anxiety in this type of learning environment. Thus, trainees given exploratory learning conditions should exhibit significantly higher levels of knowledge and performance when encouraged to make rather than avoid errors. In contrast, the nature of error instructions should have less of an impact for individuals given proceduralized instruction. Since proceduralized instruction reduces the number of errors trainees make, the negative impact of error avoidance on individuals' self-efficacy and anxiety may not be as strong. Similarly, the positive benefits of error encouragement should be minimized because proceduralized instruction reduces the opportunity for errors and the adoption of a learning orientation. Thus, trainees given proceduralized instruction should exhibit relatively similar levels of knowledge and performance when encouraged to make and avoid errors.

Hypothesis 20: The instructional and motivational elements of error training interact such that the nature of error instructions has a much stronger relationship with knowledge and performance when individuals are given exploratory learning conditions than when they receive proceduralized instruction.

Instructional element x emotional element. I also expect that the instructional element will interact with the emotion-control element to influence individuals' knowledge and performance. In exploratory learning, individuals must discover task strategies and principles on their own, determine what material to study and practice, and diagnose their errors and determine how to redirect their efforts. In proceduralized instruction, however, individuals are provided step-by-step instructions and are essentially guided through the learning process. Thus, exploratory learning requires greater cognitive effort than proceduralized instruction. As discussed earlier, negative emotions, such as anxiety, divert attentional resources away from on-task activities. This may be particularly detrimental when individuals are engaged in exploratory learning because resource demands are high. Thus, emotion control strategies should have a greater impact on the knowledge and performance of individuals given exploratory learning than those given proceduralized instruction. In other words, the positive effects of an emotion-control intervention should be greater for individuals who are engaged in the effortful process of exploratory learning.

Hypothesis 21: The instructional and emotional elements of error training interact such that the emotion-control intervention has a stronger relationship

with knowledge and performance when individuals are given exploratory learning than when they receive proceduralized instruction.

Motivational element x emotional element. I also expect that the motivational and emotional elements of error training will interact to influence individuals' knowledge and performance. As described above, error encouragement is expected to create a learning orientation and error avoidance is expected to facilitate a performance-avoid orientation. As a result, error encouragement should decrease individuals' anxiety, while error avoidance should increase trainees' level of anxiety. It follows, therefore, that an emotion-control intervention should yield a greater benefit for individuals told to avoid errors. These individuals will be more likely to experience anxiety and performance pressure, which may hurt their learning and performance. However, the emotion-control intervention may serve to ameliorate these negative emotions and increase knowledge and performance. Individuals encouraged to make errors, however, will have lower levels of anxiety and feel less pressure to perform. Thus, the emotion-control intervention should be less important for individuals encouraged to make errors. As a result, I suggest that emotion-control intervention will have a more positive impact on the knowledge and performance of individuals told to avoid errors than those told to make errors.

Hypothesis 22: *The motivational and emotional elements of error training interact such that the emotion-control intervention has a stronger relationship with trainees' knowledge and performance when they are given error avoidance instructions than when they are given error encouragement instructions.*

Instructional element x ability. A number of researchers have suggested that different instructional formats may be more or less effective depending of the ability level of trainees. Snow (1986), for example, reported that students with lower levels of ability typically benefit from tightly structured lessons, whereas students with higher levels of ability tend to perform better in less structured error-filled environments that provide room for independent learning. Individuals high in ability may be better equipped than low ability individuals to make effective use of the control offered by exploratory learning. For example, they may be more effective at using hypothesis-testing to learn complex relations in a task. In addition, exploratory learning increases cognitive workload (Schönpflug, 1985; Tuovinen & Sweller, 1999). While high ability trainees may benefit when they focus attention on activities such as error correction and the monitoring of progress, these activities add an additional layer of complexity that consumes the already limited cognitive resources of low ability trainees. Thus, I predict that exploratory learning will benefit high ability trainees, but hurt low ability trainees, while proceduralized instruction will hurt high ability trainees, but benefit low ability trainees.

Hypothesis 23: Type of instruction interacts with trainees' cognitive ability to influence basic and strategic knowledge and performance. Specifically, individuals high in ability exhibit higher levels of knowledge and performance under exploratory learning than proceduralized instruction; however, individuals low in ability exhibit higher levels of knowledge and performance under proceduralized instruction than exploratory learning.

Instructional element x openness to experience. Past research has shown that individuals high in openness to experience tend to display greater training proficiency than individuals low in openness to experience (Barrick & Mount, 1991). However, this relationship may depend on the nature of the training situation. Gully et al. (2002), for example, found a positive relationship between openness to experience and training outcomes when training encouraged errors, but these relationships disappeared when errors were discouraged. They suggest that these results may be due to the fact that error training encourages exploration and trainees higher in openness are more likely to engage in exploratory behaviors. In other words, there may be a good fit between individuals high in openness and the active, exploratory nature of error training. Individuals low in openness to experience may be less willing to explore the task and, therefore, may benefit less from situations that create exploratory learning conditions. Based on these findings, I predict that exploratory learning will benefit individuals high in openness to experience, but have relatively little effect on individuals low in openness to experience. Conversely, proceduralized instruction should have a negative influence on the learning and performance of individuals high in openness to experience, but relatively little effect for individuals low in openness to experience.

Hypothesis 24: Type of instruction interacts with individuals' openness to experience to influence basic and strategic knowledge and performance. Specifically, individuals high in openness exhibit higher levels of knowledge and performance under exploratory learning than proceduralized instruction; however, individuals low in openness exhibit similar levels of knowledge and performance under both types of instruction.

Motivational element x conscientiousness. Individuals high in conscientiousness tend to be thorough, responsible, organized, achievement-oriented, and hardworking (Barrick & Mount, 1991; Martocchio & Judge, 1997). In addition, conscientious individuals tend to be cautious and avoid mistakes. In contrast, individuals low in conscientiousness tend to be less cautious, through, and responsible. They also tend to be less averse to making mistakes. As a result, conscientiousness typically displays a positive relationship with achievement outcomes, such as performance. However, the research by Gully et al. (2002) suggests that the effects of conscientiousness may depend on whether errors are encouraged or discouraged. Specifically, Gully and colleagues found that task instructions that encouraged errors led to more positive outcomes for individuals low in conscientiousness, but more negative outcomes for individuals high in conscientiousness. In contrast, instructions that discouraged errors benefited individuals high in conscientiousness, but hurt individuals low in conscientiousness. The authors suggest that conscientious individuals do not benefit from error encouragement because it is inconsistent with their personality.

Hypothesis 25: Type of error instructions interacts with conscientiousness to influence basic and strategic knowledge and performance. Specifically, individuals high in conscientiousness have higher levels of knowledge and performance in the avoid errors than the make errors condition; however, individuals low in conscientiousness have higher levels of knowledge and performance in the make errors than the avoid errors condition.

Emotion-control x ability. It is expected that the emotion-control statements will have a greater effect on the knowledge and performance of low ability trainees than high

ability trainees. Low ability individuals are more likely to make errors than high ability individuals, which, in turn, is likely to lead to greater levels of anxiety. In addition, anxiety is likely to have a more detrimental effect on the knowledge and performance of low ability individuals because of their limited cognitive resources. So, an intervention that helps individuals to control their emotions should have a more pronounced impact on the knowledge and performance of low ability individuals. Consistent with these arguments, Kanfer and Ackerman (1990) found that their emotion-control intervention benefited low ability trainees, but not high ability trainees.

Hypothesis 26: The emotion-control statements interact with trainees' ability to influence basic and strategic knowledge and performance. Specifically, low ability trainees exhibit significantly higher levels of knowledge and performance in the emotion-control training condition; however, high ability trainees exhibit similar levels of knowledge and performance in the emotion-control and no emotion-control conditions.

Emotion-control x trait anxiety. Research on the topic of anxiety has made a clear distinction between state and trait anxiety (e.g., Gaudry, Vagg, & Spielberger, 1975; Spielberger, 1985). Whereas state anxiety represents a more localized, temporal condition, trait anxiety is a measure of an individuals' natural, or dispositional, level of anxiety. Trait anxiety is often interpreted as a measure of how anxiety prone an individual is. A study by Spielberger (1977), for example, found that among those subjects exposed to an anxiety manipulation, individuals with higher trait anxiety showed a greater increase in state anxiety. Spielberger concluded that the anxiety trait implies a greater susceptibility to influences from situations. Differences in trait anxiety, therefore,

may play an important role in determining the impact of an emotion-control intervention. Individuals who are anxiety prone are more likely to react negatively to events, such as errors, and be distracted by the worry and anxiety that accompanies them. In contrast, individuals who have relatively low levels of trait anxiety will be less likely to develop anxiety and, therefore, be distracted by their emotions. As a result, the emotion-control statements included in error training should be especially important for individuals high in trait anxiety, because of their enhanced susceptibility to state anxiety.

Hypothesis 27: The emotion-control statements interact with individuals' trait anxiety to influence basic and strategic knowledge and performance. Specifically, individuals with high levels of trait anxiety display significantly higher levels of knowledge and performance in the emotion-control condition; however, individuals with low levels of trait anxiety display similar levels of knowledge and performance in the emotion-control and no emotion-control conditions.

The hypotheses outlined in the sections above are summarized in Table 1. The hypotheses examine the effects of the three elements of error training on not only knowledge and performance but also numerous process variables. As can be seen in Figure 1, the process variables are expected to mediate the relationships between the elements of error training and knowledge and performance. Although not stated as explicit hypotheses, this mediation was tested for in the analyses. In addition, I did not explicitly hypothesize relationships between the individual difference variables and knowledge and performance, or between knowledge and training performance and generalization. This is due to the fact that past research has clearly established these relationships. These relationships are examined in the analyses to demonstrate

consistency with previous research findings. Finally, the interactions are hypothesized to have significant effects on knowledge and performance. These interactive effects may be explained by the process variables; therefore, any significant effects in Hypotheses 20 through 27 were further explored by examining the impact of the significant interactions on relevant process variables.

METHOD

Participants

Participants were 350 undergraduates from a large midwestern university. Fifty-eight percent of the trainees were female, 83 percent were Caucasian, and most (89.4%) were between 18 and 21 years old. Participants were recruited from the Psychology subject pool, and they received course credit for their voluntary participation (see Appendix A).

Design

The present study employed a 2 (exploratory learning vs. proceduralized instruction) x 2 (error encouragement vs. error avoidance) x 2 (emotion-control intervention vs. no emotion-control intervention) fully crossed between-subjects design. Participants within experimental sessions were randomly assigned to one of the eight resulting conditions.

Task

The PC-based decision making simulation TANDEM (see Kozlowski & Gully, 1996; Weaver, Bowers, Salas, & Cannon-Bowers, 1995; Weaver, Morgan, Hall, & Compton, 1993) served as the experimental platform. This platform is a low physical fidelity simulation of a naval radar tracking task, which provides a high psychological fidelity for complex and difficult decision making and information processing tasks. The task was originally developed by the Naval Air Warfare Center Training Systems Division (NAWCTSD) and the University of Central Florida. The original task has undergone extensive design modifications to create the current version of TANDEM (version 8.1f), which provides a dynamic, self-contained, and completely novel task

environment. The current version of TANDEM allows researchers to examine the process of training individuals on a complex task and developing adaptive expertise. The simulation was designed to include events that unfold in real time that can be scripted by the researcher. In addition, the researcher has control over what performance information trainees are given, what decisions they need to make, and how the performance of these actions are scored.

The current version of TANDEM, which was used in this study, is referred to as the Tactical Action Game (TAG). During TAG, each participant is seated at a simulated radar console upon which multiple contacts are presented. The trainee must gather information about each contact by “hooking” the target, gathering information about its characteristic “cue values,” and making a final decision about the target’s disposition based on information gathered. Using this information, the trainee then makes a final decision about what action to take against the target (shoot or clear). Three cues are available for each of the component decisions (nine cues overall), which must be made in the following order: (1) Type (air, surface, or submarine); (2) Class (civilian or military); (3) Intent (peaceful or hostile); and (4) Engage (shoot or clear).

Skill components. Throughout training, all participants had access to a comprehensive training manual. During a 2.5-minute period before each trial, the manual was presented on-line so as to provide the capability of tracking the content and duration of studied material. Three sets of skills are documented in the comprehensive manual. These sets included basic functionality, declarative knowledge, and strategic knowledge.

Basic functionality on the task involves learning those features of the program, in terms of both hardware and software, which make it possible to perform the task. Task

features which must be learned in order for a participant to perform well on TAG include hooking targets, accessing cue menus, and “zooming” to alter the display radius. In addition, individuals need to understand several basic functions of a PC, such as using a mouse and keyboard.

Declarative knowledge is also required to process information and render target sub-decisions. The cue information is accessed from pull-down menus, with 3 cues available for each of the three component decisions. Based on the cue information provided, individuals must determine the Type (air, surface, submarine), Class (civilian or military), and Intent (peaceful or hostile) of each target. After making these sub-decisions, participants are required to either shoot targets (if hostile) or clear them from the radar screen (if peaceful). To make correct decisions, individuals must not only learn the cue values but also must learn the proper procedure for making target decisions. For example, individuals must make the Type decision first, followed by the Class decision, and then the Intent decision. If they do not make the decisions in this order or do not make all the sub-decisions, they will not be allowed to make a final target decision. Also, sometimes the radar will provide a conflicting cue value for a target. When this occurs, individuals must choose the option indicated by the majority of cues (2 out of 3).

For individuals to successfully progress to learning the strategic aspects of the game, it is important that they first become proficient at making correct and efficient component and final engagement decisions. These skills, which are a foundation for later strategic skills, are measured by indicators of basic performance, such as number of correct sub-decisions and final engagement decisions.

Strategic knowledge involves the participant's ability to understand the deeper elements of the simulation and to develop two critical strategic skills: situational assessment and target prioritization. Three elements of the task (using the zoom function, identifying defensive perimeters, and locating and utilizing marker targets) are relevant to situational assessment. The zoom function allows participants to either expand (zoom out) or constrict (zoom in) the radius of their radar screen. Participants need to "zoom out" to determine the overall situation in which they are operating. This action is critical because of the presence of two "defensive perimeters" within the task. The inner defensive perimeter, located at 10NM, is clearly marked and easy for participants to identify. However, the outer perimeter, located at 256 NM, is beyond the initial viewing range of 32 NM, and is not clearly marked. Thus, participants must first "zoom out" and then locate "marker targets" that serve to identify the outer boundary.

Target prioritization requires the trainee to utilize a separate set of strategic skills. Decisions about which targets constitute the greatest threats to the participant's defensive perimeters are critical, as the scenarios are designed so there is often multiple targets approaching each perimeter, some of which are more threatening than others. The order in which targets should be prosecuted should be based on two pieces of information, speed and distance from the perimeter. Faster targets are of higher priority than slower targets because they will penetrate the defensive perimeters more quickly. Also, targets close to either of the defensive perimeters are of higher priority than those that are farther away. Thus, the highest priority targets are those that are both (a) moving quickly and (b) near a defensive perimeter. Trainees also need to "trade off" targets approaching their

inner and outer perimeters. Strategic decisions related to such trade-offs revolve around the number of targets at each perimeter, their priority, and their “cost” if they penetrate.

Errors in TANDEM. There are a variety of errors that trainees can make while performing the TANDEM simulation. These errors relate to both basic (e.g., decision-making) and strategic (e.g., preventing perimeter intrusions) aspects of the task. In this section, I briefly outline these errors. I use the taxonomies presented earlier to classify these different types of errors as either skill-based, rule-based, or knowledge-based. I also discuss how trainees recognize that they have made these errors (e.g., sources of error detection). This discussion is summarized in Table 2.

Knowledge-based errors occur when a person is unable to carry out a task or plan due to incomplete or incorrect knowledge. Because TANDEM is a novel task, there is great potential for knowledge-based mistakes, particularly in the early stages of training. In TANDEM, individuals must acquire knowledge of important task concepts and principles to perform well on both basic and strategic aspects of the task. In terms of basic performance, trainees must learn the cue values for different types of targets in order to make correct decisions. They must also learn the correct decision sequence for prosecuting targets. Without this knowledge, trainees will make decision errors or will be prevented by the system from making final engagement decisions. To perform well on more strategic aspects of the task, trainees must acquire knowledge of several key task concepts and principles. For example, they need to learn how to use the zoom function to view all targets located on the radar screen and to identify and monitor the outer perimeter. Trainees who do not use the zoom function or who use it too infrequently will experience a greater number of perimeter intrusions and be unaware of changes in

environmental conditions. Trainees also need to learn how to find marker targets that identify the location of the outer perimeter and must learn about the characteristics of pop-up targets that appear suddenly on the screen and understand the impact that these targets can have on their performance. Finally, trainees need to learn how to prioritize targets based on their speed and proximity to the perimeters.

In TANDEM, knowledge-based errors are highlighted by various environmental cues and feedback functions. Immediately following the prosecution of each target trainees receive feedback on the validity of their decisions. In addition, all trainees are given post-trial feedback concerning correct and incorrect target decisions. This feedback allows trainees to recognize when they do not know the cue values for different targets. Also, TANDEM includes a forcing function that prevents trainees from making a final engagement decision when they do not make the sub-decisions in the appropriate sequence. Trainees are also given post-trial feedback on strategic aspects of the task, such as the number of times they used the zoom function, the number of pop-up and marker targets hooked, and the number of high priority targets prosecuted. This feedback highlights a lack of knowledge in key strategic areas. Furthermore, trainees can visually observe when targets cross perimeters, which also provides information concerning ineffective application of strategic concepts.

Knowledge-based errors in TANDEM impact both basic and strategic task performance. When individuals do not know the cue values or decision sequence, they will make incorrect decisions and their basic performance will suffer. These errors highlight for trainees areas in which they need to increase their knowledge. When individuals do not know how to use the zoom function, how to locate the outer perimeter,

how to watch for pop-up targets, or how to identify high priority targets, they will allow a greater number of perimeter intrusions and their strategic performance will suffer. Errors in each of these areas can indicate a lack of knowledge of important task concepts and can encourage trainees to update or revise their mental model of the system.

Rule-based errors occur during the problem-solving process. In rule-based errors, a person's actions proceed as planned, but the plan itself is inadequate or inappropriate. Rule-based errors arise because an individual misclassifies a particular situation and, therefore, applies an inappropriate rule. Individuals must not only possess task knowledge but must also know when and how to apply that knowledge. In other words, rule-based errors do not occur because an individual lacks knowledge or skills, but rather because an individual does not make proper decisions regarding "which, why, when, and where" to apply his or her knowledge and skills (Ford & Kraiger, 1995; Gagné & Merrill, 1992; Tennyson & Breuer, 1997). TANDEM is a dynamic task and, as such, the nature of the task situation changes from trial to trial. For example, the number of targets distributed at the inner and outer perimeters changes across the various scenarios. As a result, individuals must recognize changes in task characteristics and modify their plans and strategies accordingly. Although the underlying components of knowledge do not change, individuals must alter when, why, and how they apply this knowledge based on changes in task characteristics (e.g., contextual or strategic performance; Ford & Kraiger, 1995). To prevent perimeter intrusions, individuals need to focus different levels of attention on the inner and outer perimeters depending on how the targets are distributed. Furthermore, trainees will need to zoom out and view the "big picture," so as to determine the nature of the task environment. If trainees do not recognize these changes

in task characteristics, they may apply a rule that was effective in a past scenario but is inappropriate given current conditions.

Research has demonstrated that rule-based errors can be difficult to detect. Individuals often recognize when their actions do not proceed as planned, but it is more difficult to recognize that the plan itself is inappropriate. As a result, a number of feedback mechanisms are included in TANDEM to facilitate the detection of rule-based errors. Trainees receive extensive post-trial feedback concerning perimeter intrusions, the prosecution of high and low priority targets, and the use of the zoom function. This feedback will serve to highlight when trainees have applied ineffective rules or strategies to prevent targets from crossing the perimeters. Finally, during task performance individuals can see when targets cross the perimeters. This provides trainees with immediate feedback that their current strategy is ineffective for preventing perimeter intrusions.

Rule-based errors in TANDEM primarily impact strategic performance. The decision-making protocol is held constant across the scenarios, so trainees do not need to alter strategies that impact basic performance. However, if trainees do not recognize changes in target distributions, they will allow a number of perimeter intrusions and exhibit lower levels of strategic performance. When these errors occur, individuals learn that their current strategy is ineffective and they must develop a new approach to preventing perimeter intrusions. Also, the feedback they receive with respect to these errors can help them identify why their plan is deficient (e.g., focusing only on inner perimeter, prosecuting too many low priority targets) and facilitate the development of more effective strategies.

Skill-based errors are lower-level errors that result from some failure in the execution stage of an action sequence. Skill-based errors are unintended actions that often arise from inappropriate attentional monitoring. Reason (1990) refers to skill-based errors as slips and lapses and Zapf and Frese (Zapf et al., 1992) classify skill-based errors as sensorimotor errors. On most tasks, skill-based errors occur during the later stages of learning when performance is more automatic. Consistent with Zapf and Frese's computer-based error taxonomy, skill-based errors in TANDEM typically arise from stereotyped and automatic movements, such as clicking the wrong mouse button or typing an incorrect key. For example, when making cue decisions in TANDEM trainees may accidentally click the wrong menu option. In addition, targets are often located close to one another on the radar screen and, as a result, trainees often accidentally click on and hook an unintended target. These errors typically occur because trainees are not focused on the task or are working too quickly. Lapses can also occur in TANDEM. For example, after trainees make the three sub-decisions for a target they then have to make a final engagement decision. This process is pretty straightforward – if a target is peaceful they must decide to clear it from the screen and if it is hostile they must choose to shoot the target. However, if trainees are not focused or are distracted, an error may occur in the storage stage of the intention and trainees may make an incorrect final engagement decision.

Research has shown skill-based errors tend to be easily detected by the individuals who make them. This is also the case in TANDEM. Often when an individual hooks an incorrect target or clicks the wrong menu option, they recognize this error immediately because the wrong target or menu option is highlighted. In other

words, the environment provides immediate feedback that the individual has made an error. In addition, TANDEM provides trainees with immediate feedback on the validity of their decisions as well as decision feedback following each trial. This feedback will serve to highlight the various skill-based errors, particularly if trainees are confident that they know the target cue values.

Because most skill-based errors in TANDEM occur during target classification, these errors impact trainees' basic performance. If an individual accidentally chooses the wrong cue value or makes an incorrect final engagement decision, he or she will lose points and exhibit lower levels of basic performance. When individuals make these skill-based errors, they learn that it is important to focus their attention on the task and to avoid proceeding too quickly through the decision sequence. This can be important during the later stages of learning when individuals' attention may wander or they are testing the limits of effective performance. In addition, they may develop useful skills as a result of their skill-based errors. For example, individuals can use the zoom function to increase the space between targets. When they zoom out there is greater separation between targets around the outer perimeter, and when they zoom in there is greater separation between targets at the inner perimeter. This zooming process not only separates targets but also allows trainees to acquire more accurate picture of the task situation. Thus, the error of hooking an unintended target may facilitate the use of an effective task strategy.

Procedure

On-line signup. Participants registered for the current study through the Psychology subject pool website. After selecting a date and time to participate in the experiment, participants read a consent form that pertained only to the on-line section of

the experiment (see Appendix B). Next, participants completed an on-line questionnaire designed to collect demographic information and measure participants' cognitive ability, trait goal orientation, trait anxiety, openness to experience, and conscientiousness. This on-line portion of the experiment took about 30 minutes.

Demonstration and familiarization. When participants arrived at the lab for the training portion of the experiment, they were asked to complete a second consent form (see Appendix C). Also, participants signed an SAT/ACT release form that allows access to their test scores from the Registrars Office (see Appendix D). The experimenter then read a short introduction to the experiment and presented participants with a brief demonstration of the task, outlining its features and decision sequence. During this demonstration, the experimenter briefly displayed how to hook targets, use the pull down menus, use the zoom function, and make decisions in the proper order. The experimenter demonstrated how to use the on-line manual and how to scroll through the feedback.

Following the demonstration, the experimenter introduced the emotion-control manipulation (explained more detail in the Emotion-control Manipulation section below). Participants then had an opportunity to get familiar with the on-line instruction manual in a 2.5 minute study period and then were able to practice the TAG game in a one-minute "familiarization" trial. The purpose of this preliminary trial was to give participants an opportunity to learn how to operate the manual and task and to get familiar with the equipment. Participants did not receive feedback for the familiarization trial and the study and performance data is not included in any of the analyses reported in this study.

Practice. After the familiarization trial, trainees began the practice section of the training program. The practice section consisted of three blocks, each block consisting of

three trials, for a total of nine training trials. Each training trial was composed of a cycle of study, practice, and feedback. Participants had 2.5 minutes to study an on-line manual that contained information on all important aspects of the task, four minutes of hands-on practice, and 1.5 minutes to review their feedback. Veridical feedback on all aspects of the task relevant to both basic and strategic performance was provided immediately following the completion of each practice trial. Although the specific nature of the feedback was based on each trainee's performance, all trainees received feedback on the same task dimensions. One piece of information given in the feedback was score. Task score was computed by adding 100 points to the trainee's score every time a target was identified and prosecuted correctly, and subtracting 100 points from the trainee's score each time a target was misidentified or prosecuted incorrectly. In addition, 10 points were deducted from the trainee's score for each target that crossed a defensive perimeter. In addition to score, the feedback provided information concerning the trainee's performance on both basic and strategic task skills. Furthermore, specific feedback was provided on the errors that trainees make during each trial (described in greater detail below). An example of the general feedback is provided in Appendix E.

Prior to each training block, the experimenter introduced the instructional and motivational manipulations (described in more detail in the Instructional Manipulation and Motivational Manipulation sections below). Following the third and ninth practice trials, participants completed measures of hypothesis-testing, metacognitive activity, state goal orientation, intrinsic motivation, self-efficacy, state anxiety, and feelings of control. In addition, participants completed a basic and strategic knowledge test following the

third and ninth trials. Participants were given a 5-minute break following the third and ninth trials.

Transfer. Following the training blocks, trainees participated in two additional trials designed to measure the extent to which they could transfer their skills and knowledge. In the first trial, the task possessed a format similar to the training trials. This trial was designed to measure individuals' near transfer performance (e.g., training performance). Trainees received feedback regarding only their score on this trial.

The near transfer test was followed by a far transfer or generalization trial, in which the workload (e.g., more targets, length of the trial was doubled) and complexity (e.g., the principles and rules underlying task proficiency were modified) of the task was increased. To increase the workload, the number of targets was increased from 22 to 60, a 172% increase. In addition, the length of the generalization trial was increased from five to ten minutes. Task complexity was heightened by (1) including more "pop-up" targets, which appeared suddenly on the screen; (2) changing the "rules of engagement" so that a greater number of points were deducted when targets crossed the visible inner perimeter (175 points) and the invisible outer defensive perimeter (125 points); (3) creating more defensive perimeter intrusions; (4) creating "pop-up" targets that appeared very close to defensive perimeters; and (5) differentially distributing boundary intrusions to create a situation in which many targets threatened the outer perimeter, while fewer targets threatened the inner perimeter, requiring strategic trade-offs on the part of trainees. Following the near transfer test, trainees received instructions describing the important task differences they would encounter in the far transfer session. Effective

performance on the generalization trial required that trainees adapt the knowledge and skills they have acquired throughout training to a new and more complex situation.

After completing the far transfer trial, trainees had an opportunity to review their score. Finally, participants were fully debriefed and dismissed (see Appendix F). In its entirety, the experimental session lasted 3 hours.

Incentives. Cash awards were offered for (a) questions answered during the training trials (knowledge) and (b) performance on the final two trials. The instructions at the beginning of training indicated that trainees would be asked to answer questions throughout the training program, emphasizing that they needed to “...think carefully about your answers to the questions.” They were told that awards would be given to the four players who answered these questions the best, and that four additional awards would be given to the players who did the best on the final (far transfer) trial. Written instructions regarding incentives were provided to trainees at the beginning of the experiment, and they were reminded of the incentives by the experimenter just prior to the start of the generalization trial. These instructions are presented in Appendix G.

Manipulations

Instructional manipulation. The instructional manipulation determined the type of learning strategy or approach used by participants to develop an understanding of the task. Participants in the exploratory learning condition received little guidance and were instructed to explore the task to discover the best strategy to handle the situation. In contrast, participants in the proceduralized instruction condition were given step-by-step instructions that guided them through each scenario. These two types of instructions are consistent with not only past research on error training but also other research that has

compared exploratory/discovery learning and proceduralized instruction (e.g., Smith, 1996). I describe this instructional manipulation in greater detail below.

Prior to each of the three training blocks, all participants received a list of topics that they should focus on learning during the following three trials. These topics were designed to provide a context for the proceduralized instructions and also to provide minimal structure for people in the exploratory learning condition. Past research has shown that minimal guidance is needed for exploratory learning to be effective. In the first block, participants were instructed to focus on learning how to make correct target decisions and learning how to operate basic features of the simulation. In the second block, participants were told to learn how to prevent targets from crossing the perimeters. To do this effectively, participants were told they needed to learn how to use the zoom function, how to use marker targets that identify the location of the outer perimeter, and how to watch for pop-up targets that appear suddenly on the screen. Finally, in the third block participants were told they needed to learn how to prioritize targets and how to make trade-offs between targets that are approaching the inner and outer perimeters. These practice topics are presented in Appendix H.

After being given the practice topics for a training block, the experimenter introduced the instructional manipulation. Participants in the exploratory learning condition were instructed to explore the task to learn the skills for the session. They were told to explore the task to understand what is occurring in the scenario, and to discover the best strategy to deal with the situation. In addition, these participants were encouraged to experiment with the task to learn the various skills. Individuals in this condition were able to use the computerized manual to learn about aspects of the task

(e.g., making target decisions, zoom function), but did not receive step-by-step instructions during the scenarios. This is consistent with the instructional approach utilized in error training (e.g., minimalist training). The absence of step-by-step instructions should have increased the number of errors that these individuals experienced. A sample of the exploratory learning instructions is provided in Appendix I.

Participants in the proceduralized instruction condition received descriptions of the scenarios as well as a general overview of the tasks they needed to perform and the strategies that they should practice during the scenarios. In addition, they were given step-by-step instructions on how to perform each of the skills/strategies outlined on the topics sheet. Furthermore, they received all the commands necessary to complete each task function. Consistent with past studies on error training (e.g., Frese et al., 1991), these instructions minimized the probability of error but did not give specific explanations for the steps and commands. The experimenter provided participants with a sheet that contained these instructions and provided an overview of the instructions to make sure they were understood. These instructions were designed to be consistent with past studies that have employed proceduralized instruction. In addition, these instructions should have greatly reduced the number of errors that trainees experienced.

The proceduralized instructions corresponded to the tasks outlined prior to each training block. So, in the first three trials individuals were guided through the decision-making process and basic operation of the simulation. In the second block, they focused on preventing perimeter intrusions and were instructed on how to use the zoom function, how to identify the perimeters, and how to watch for pop-up targets. Finally, in the last

block of trials participants were given explicit instructions on how to prioritize targets and make trade-offs. Examples of these instructions are provided in Appendix J.

Motivational manipulation. The motivational manipulation involved the type of error instructions that trainees were given throughout training. After trainees were given the training topics for each block, they were given a list of potential errors that one can make in these areas. This is important because trainees encouraged to make or avoid errors must know what constitutes a mistake. Indeed, past research on error training has often provided individuals with explicit descriptions of potential errors that one can make on the task (e.g., Frese & Altmann, 1989; Gully et al., 2002).

After listing potential errors that can occur with respect to each of the training topics, the instructions either encouraged or discouraged trainees from making these errors. Consistent with the typical error training approach, trainees in the error encouragement condition were instructed to make errors. They were told that errors should be expected and that they are a positive part of the learning experience. In contrast, individuals in the error avoidance condition were told to avoid making errors. They were told that errors are something to avoid and that learning is more effective when one makes fewer errors. These instructions are similar to those used in past research (e.g., Gully et al., 2002; Nordstrom et al., 1998) and were provided not only prior to each training block but also periodically throughout training by the experimenter to reinforce either an error encouragement or error avoidance focus. A sample of these instructions is provided in Appendix K.

As discussed in the section on errors above, trainees received feedback on their errors not only from environmental cues but also from feedback functions built into the

TANDEM simulation. To ensure that trainees were able to track their errors, explicit feedback was provided following each trial on errors committed. Although trainees were able to deduce the errors they made on all aspects of the task from the general feedback, this explicit error feedback focused only on errors committed on the training topics for each block. An example of this feedback is presented in Appendix L.

Emotion-control manipulation. The emotion-control manipulation determined whether or not participants received emotion-control training and statements. Individuals in the emotion-control condition received this training following the task demonstration. The experimenter introduced the emotion training by discussing the negative effects of anxiety and frustration on learning and performance. Participants were told that anxiety uses up valuable resources that they should be applying to the task. The experimenter also described the role of self-dialogue in both increasing and decreasing the amount of frustration and anxiety that one experiences. Participants were told that positive and constructive thoughts can be used to decrease anxiety and that negative and self-defeating thoughts often increase one's level of anxiety.

After this general overview of negative emotions and the role of self-talk in controlling emotions, the experimenter introduced the emotion-control statements. Because the current study teases apart the roles of emotion-control and error encouragement, the standard error training statements were not used. Many of the statements used in past research explicitly encourage errors (e.g., "I made an error. Great!"), which confounds the impact of error encouragement and emotion-control training (e.g., positive self-talk). Although these specific statements were not used, the

statements employed in the current study were designed to achieve a similar goal - reduce trainees' anxiety and frustration surrounding errors and poor performance.

The statements used in the present study are presented in Appendix M. These statements were drawn from past research in areas such as Rational Attitude Training and Thought Self-Leadership and other work on self-talk by researchers such as Bloom (1985) and Butler (1983). In the beginning of training, the experimenter presented participants with a sheet that contained these statements and read through them aloud. In addition, the emotion-control statements were presented on a whiteboard in the training room and were presented on the computer periodically for reinforcement. The experimenter explained to participants how to recognize when they were engaging in negative self-talk and discussed the negative impact these statements have on learning and performance (Butler, 1983). Participants were told to repeat the statements, or other positive self-statements of their own design, whenever they felt anxious or frustrated, or when they noticed they are engaging in self-defeating or negative thoughts. Participants were also encouraged to periodically repeat positive statements to themselves to prevent negative thoughts and maintain a positive "CAN DO" attitude. Participants were told that repeating positive statements would help them control their negative emotions and would allow them to better focus on the task at hand.

Measures

As indicated previously, participants were asked to complete several measures on-line when they registered for the experiment. These measures collected demographic information on participants and also assessed individuals' cognitive ability, trait goal

orientation, conscientiousness, openness to experience, and trait anxiety. These on-line measures are presented in Appendix N.

Several active learning processes and training outcomes were also assessed during the experimental session. Following the third and ninth practice trials, participants completed measures of hypothesis-testing, metacognitive activity, state goal orientation, intrinsic motivation, self-efficacy, state anxiety, and feelings of control. In addition, following the third and ninth trials individuals completed basic and strategic knowledge tests. These measures are presented in Appendix O.

Several measures were also created from data collected by the task.¹ The FASTBACK feedback program was used to calculate how much time individuals spent evaluating their feedback during each block of three trials. This information provides a measure of the extent to which participants engaged in self-evaluation activities, which are an important part of the self-regulatory process. The on-line training manual also recorded how much time individuals spent studying prior to each trial. The amount of time individuals spent studying during each block of three trials was used as a measure of cognitive effort. Finally, data collected from the TANDEM simulation allowed for an assessment of individuals' overall as well as basic and strategic performance on the near and far transfer trials. All of these measures are described in greater detail below.

Cognitive ability. Cognitive ability was measured by having individuals report their highest score on the SAT or ACT. Individuals were assured that this information would be kept strictly confidential and would be used for research purposes only. In addition, participants were asked to sign a release form that allowed the experimenter to obtain participants' test scores from the Registrars office. Scores were only requested

from the Registrar when participants indicated that they could not remember their score on the SAT or ACT. SAT or ACT scores were collected for all but three participants. The mean cognitive ability score for the sample was used for these three individuals. Researchers generally agree that the SAT and ACT have a large general cognitive ability component (Hunter, 1986; Phillips & Gully, 1997; Schmidt, 1988). In addition, the publishers of these tests claim high internal consistency reliabilities (e.g., above .80) for their measures. Individuals' ACT or SAT scores were standardized using 2001 norms published by ETS and ACT, and this standardized score was used as a measure of cognitive ability. If individuals provided both an ACT and SAT score, the standardized ACT score was used. The ACT score was adopted in this situation because 97% of participants provided an ACT score and, therefore, utilizing this score enhanced consistency of measurement across participants.

Trait goal orientation. Before the experiment, participants completed Button, Mathieu, and Zajac's (1996) trait goal orientation measure, and a version of Vandewalle's (1997) trait goal orientation measure that was modified to be domain-general, instead of specific to the work domain. Button et al.'s (1996) measure of goal orientation has been used widely within the field of organizational behavior. It is a two-dimensional measure that assesses individuals' learning and performance trait goal orientations. Vandewalle's (1997) measure is based on a three-factor model of goal orientation, which divides performance orientation into performance-approach orientation and performance-avoid orientation. Whereas research has demonstrated the Button et al. measure to be a valid predictor of multiple affective, cognitive, and behavioral outcomes,

support for VandeWalle's scales is not as well established. Thus, the decision was made to collect both measures and decide based on the data which measure is more appropriate.

After examining the data, the choice was made to use VandeWalle's three-dimensional measure of trait goal orientation. This decision was made based on two primary considerations. First, data screening revealed that the Button learning and performance orientation measures had high skewness and kurtosis. Both scales had a strong negative skew because the majority of cases clustered around values at the high end of the scale. The VandeWalle scales displayed considerably less skewness and kurtosis and were, in general, more normally distributed. Second, a recent study by Dobbins, Bell, and Kozlowski (2002) showed, using data similar to that collected in the current study, that VandeWalle's three-factor measure displayed better predictive validity than Button and colleagues measure. Also, Dobbins et al. (2002) found that the pattern of relationships between VandeWalle's three dimensions of trait goal orientation and the training processes examined was cleaner and more consistent with the theoretical foundation of achievement motivation. Based on these findings, the decision was made to use VandeWalle's measure in the current study.

The VandeWalle (1997) measure contains 13 items, with responses made on a 6-point scale ranging from "strongly agree" (1) to "strongly disagree" (6). In the current study, these anchors were reversed to create a format consistent with the other measures on the questionnaires. Five items were used to assess learning orientation and performance-prove and performance-avoid orientations were both assessed with 4 items each. Internal consistency reliabilities (coefficient alphas) were .85 for learning

orientation, .84 for performance-prove orientation, and .83 for performance-avoid orientation. This measure is presented in Appendix N.

Conscientiousness. The on-line questionnaire assessed individuals' conscientiousness using 12 items drawn from the short form of the NEO Personality Inventory (Costa & McCrae, 1992). These 12 items assess six facets of conscientiousness: competence, order, dutifulness, achievement striving, self-discipline, and deliberation. The NEO is perhaps the most widely used and extensively validated measure of the five-factor model. The conscientiousness items were rated on a seven-point scale ranging from "strongly disagree" (1) to "strongly agree" (7). Internal consistency reliability of this scale was .82.

Openness to experience. Openness was also assessed using 12 items taken from the short form of the NEO Personality Inventory. These 12 items assess six facets of openness: fantasy, aesthetics, feelings, actions, ideas, and values. Openness was measured during the on-line questionnaire using a seven-point scale ranging from "strongly disagree" (1) to "strongly agree" (7). Coefficient alpha for this scale was .73.

Trait anxiety. The on-line questionnaire measured participants' trait anxiety using the 20-item trait-anxiety subscale of the State Trait Anxiety Inventory (STAI; Spielberger, 1983). These 20 items are rated on a four-point scale ranging from "not at all" (1) to "very much so" (4). The STAI is a widely used and extensively validated measure of trait anxiety. Individuals who score high on trait anxiety are considered to be more anxiety prone. In other words, trait anxiety measures the extent to which an individual will be influenced by situations and experience state (or situational) anxiety. Reliability of this scale was .91.

Demographic information. The on-line questionnaire asked individuals to provide information concerning their gender, age, GPA, and previous video game experience. This information is collected to allow description of the sample and to ensure that these demographics are not influencing the processes and outcomes under examination. As would be expected, GPA was significantly related to the cognitive ability measure described above ($r = .20, p < .01$). A multivariate analysis of variance showed that none of the demographic variables had a significant overall influence on the training processes and outcomes measured at the end of training. Thus, there was no need to control for these variables in the analyses reported in the current study.

Hypothesis-testing. Following the third and ninth practice trials, participants completed a six-item measure of hypothesis-testing adapted from Smith (1996). This scale measured the extent to which individuals made and tested predictions about the task, explored the task, and experimented with different task strategies. Participants rated the 6 items on a 7-point Likert-type scale ranging from “strongly disagree” (1) to “strongly agree” (7). Coefficient alpha for this scale was .80 when measured early in training and .90 when measured later in training.

Metacognitive activity. Following the third and ninth trials, participants also completed a 12-item measure of metacognitive activity adapted from Ford et al. (1998). This measure is designed specifically to examine metacognitive activity within the context of the TANDEM task. A few items were modified due to changes in task design and the focus of training. The items included in this measure assess self-monitoring of learning, the planning of learning activities, and the self-evaluation of one’s progress. All items were measured on a five-point scale ranging from “never” (1) to “constantly” (5).

Coefficient alpha for the metacognitive activity measure was .89 at Time 1 and .93 at Time 2. It should be noted that the hypothesis-testing and metacognitive activity scales were significantly correlated at both Time 1 ($r = .44$, $p < .01$) and Time 2 ($r = .67$, $p < .01$). Although there is some conceptual overlap between these two scales (e.g., strategy development), the hypothesis-testing scale is more focused on testing predictions about the task and the metacognitive scale is focused more on planning and the self-monitoring of progress. A confirmatory factor analysis run on these two scales as measured at the end of training showed that a two-factor model provided moderately good fit to the data ($\chi^2(134, N = 350) = 596.11$, $p < .01$; GFI = .82; AGFI = .78; CFI = .89; and RMSEA = .099 (.091, .108)). More importantly, the two-factor model fit significantly better than a one-factor model that combined the items from these two scales ($\Delta\chi^2 = 565.80$, $df = 1$, $p < .001$). This supports treating hypothesis-testing and metacognitive activity as two separate constructs.

Self-evaluation activity. An important component of the self-regulatory process is self-evaluation. The evaluation of progress toward some goal or standard allows individuals to revise their task strategies or goals, which facilitates the adoption of more adaptive and effective learning patterns. Metacognitive activity includes self-evaluation activities, but is also a broader construct that subsumes other self-regulatory activities such as self-monitoring, planning, and strategy development and revision. Thus, in the current study, the time individuals spent reviewing their feedback during the first three and last three trials were used as more precise indicators of self-evaluation activity early and later in training. The pattern of correlations between self-evaluation activity and self-reported metacognitive activity early in training ($r = .08$, ns) and later in training ($r = .11$,

$p < .05$) suggest these measures overlap, but at the same time largely measure separate self-regulatory activities.

Cognitive effort. The amount of cognitive effort that trainees put forth during training was calculated based on the time they spent studying the on-line instruction manual. Essentially, this measure provides an indication of the mental workload experienced by individuals during training. The computerized manual records the amount of time that individuals spend studying each page of the manual prior to each training trial. The amount of time individuals spent studying during the nine trials served as an indicator of cognitive effort. The decision was made to assess cognitive effort using study time rather than a self-report measure because the latter is more subject to potential confounds, such as performance attributions.

State goal orientation. Participants completed three four-item scales designed to measure state goal orientation following the third and ninth trials. These scales were adapted from Horvath, Scheu, and DeShon (2001). Originally, these scales were designed as trait measures and assessed individuals' general disposition. Thus, for the purposes of the current study, the wording of the items was changed to reference the experimental task and to create a more state-based measure. Similar to trait goal orientation, these scales treat state learning, performance-prove, and performance-approach orientations as separate constructs. The learning orientation scale assesses the extent to which individuals are focused on learning the task and improving their performance. The performance-prove orientation scale measures the degree to which individuals are focused on performing well (e.g., obtaining high scores) and demonstrating their competence to others, and the performance-avoid orientation scale

measures the extent to which individuals are focused on avoiding poor performance and appearing incompetent.

All items were rated on a five-point Likert-type scale with responses ranging from “strongly disagree” (1) to “strongly agree” (5). Internal consistency reliabilities for the state learning orientation measure were .88 at Time 1 and .90 at Time 2, for the state performance-prove measure they were .79 and .83, and for the state performance-avoid measure they were .83 and .88. In addition, a CFA run on the three measures at the end of training provided good support for the three-factor model of state goal orientation ($\chi^2(51, N = 350) = 162.17, p < .01$; GFI = .93; AGFI = .89; CFI = .96; and RMSEA = .079 (.066, .093)). The three-factor model also provided significantly better fit to the data than a two-factor model that collapsed the two performance orientation dimensions into a single factor ($\Delta\chi^2 = 469.86, df = 2, p < .001$).

Intrinsic motivation. Following the third and ninth trials, participants completed a seven-item measure of intrinsic motivation. This measure was drawn from Deci and Ryan’s Intrinsic Motivation Inventory (IMI). The IMI has been used in numerous experiments related to intrinsic motivation (e.g., Ryan, 1982; Ryan, Koestner, & Deci, 1991; Deci, Eghari, Partick, & Leone, 1994). The inventory possesses six sub-scales designed to assess both intrinsic motivation and self-regulation. In the current study, however, only the interest/enjoyment subscale was used, since this is considered the self-report measure of intrinsic motivation. The seven-items were rated using a five-point Likert type scale ranging from “not at all true” (1) to “very true” (7). Reliabilities for this scale were .92 early in training and .93 later in training.

Self-efficacy. Following the third and ninth practice trials, self-efficacy was assessed using an 8-item self-report measure developed for use in this research paradigm (Bell, 1999; Ford et al., 1998; Kozlowski, Gully, Smith, Brown, Mullins, & Williams, 1996). This measure assessed self-efficacy with a Likert-type scale rather than with ratings of confidence about particular aspects of the task (Hysong & Quinones, 1997; Lee & Bobko, 1994). The construct of self-efficacy is operationalized as a “task-focused, self-perception with item content specifically focused on the capability to cope and to develop methods to effectively deal with the information, decisions, and challenges of the simulation” (Kozlowski et al., 1996, p. 18). This is consistent with conceptualizations of efficacy as central to self-regulatory processes (Gist & Mitchell, 1992). Response options for this scale ranged from “strongly disagree” (1) to “strongly agree” (5). Internal consistency for this scale was .90 early in training and .92 later in training.

State anxiety. Both early and later in training, participants completed a five-item measure of state anxiety drawn from Deci and Ryan’s Intrinsic Motivation Inventory. This scale measures the extent to which individuals feel pressure and tension in relation to a target activity. Although Spielberger’s 20-item state anxiety scale is probably the most widely used measure of this construct, Deci and Ryan’s measure has been validated by past research and, therefore, provides an economical (in terms of time) alternative. The five-items were rated on a seven-point Likert-type scale ranging from “not at all true” (1) to “very true” (7). Internal consistency reliabilities for this scale were .87 at Time 1 and .84 at Time 2.

Personal control. After the third and ninth trials, participants completed a three-item measure of personal control developed by McAuley, Duncan, and Russell (1992).

This measure is part of the Revised Causal Dimension Scale (CDSII). This scale was originally developed by Russell (1982), and both the original and revised versions have been used extensively in research on attributions. Participants were instructed to think about the cause(s) of their task performance and then answer the three-items using five-point rating scales. Internal consistency reliabilities for this scale were .89 early in training and .92 later in training.

Basic and strategic task knowledge. Basic task knowledge was assessed following the completion of the first and third practice blocks (after trial 3 and trial 9). Eleven multiple-choice items focusing on the extent to which declarative knowledge about the task had been acquired were utilized, focusing on cue values and basic operating features of the task. Strategic task knowledge was also assessed following the completion of the first and third training blocks. Eleven multiple-choice items focusing on the extent to which strategic knowledge about the task had been acquired were utilized. This measure focused on aspects of the task such as locating the outer defensive perimeter and prioritizing targets.

Although past research has demonstrated that these scales measure different components of knowledge (Bell & Kozlowski, in press), a CFA was run with the knowledge measures at Time 2 to confirm the two dimensional conceptualization of task knowledge. Because the knowledge items were binary in nature, I created continuously scaled indicators by summing two or three knowledge variables. This resulted in five indicators for each of the two knowledge scales. The results showed that the two-factor model of basic and strategic knowledge provided good fit to the data ($\chi^2(34, N = 350) = 69.42, p < .01$; GFI = .96; AGFI = .94; CFI = .87; and RMSEA = .055 (.036, .073)). In

addition, the two-factor model provided significantly better fit to the data than a one-factor model that collapsed the two knowledge dimensions ($\Delta\chi^2 = 21.52$, $df = 1$, $p < .001$).

Skill-based performance. Within the task itself, data was collected that allow assessments to be made of individuals' skill-based performance. Trainees' performance was measured during training as well as in two transfer trials. Performance during training was measured during the ninth training trial. Following training, individuals participated in two transfer trials. The first trial was designed to assess near transfer performance. As mentioned previously, this trial exhibited a format similar to the training trials, all trainees received similar instructions, and the step-by-step instructions were removed for participants in the proceduralized instruction condition. The second transfer trial was designed to measure generalization, or far transfer, performance. In this trial, the characteristics of the task were modified, thereby providing a test of trainees' ability to generalize their skills to a more complex and dynamic environment.

The instructions given to trainees before the final two trials encouraged individuals to do their best and to demonstrate what they had learned and how well they could do. In addition, participants were reminded that one of the cash awards is given to the individuals who perform the best in the final two trials. Essentially, the instructions and incentives were designed to transition all participants from a training focus to a performance or demonstration of competence focus. This ensures that participants who were encouraged to make errors or explore the task would focus on displaying their knowledge and skills and not continue the same activities they used during the learning phase of training. As a result, participants' performance in the final trial serves as a valid

measure of knowledge and skills acquired during training and not some artifact of the nature of the training session.

For each of these three time periods, several measures of performance were examined. First, trainees' overall score was used as an omnibus measure of performance during training and in the near and far transfer trials. Score is calculated by adding 100 points for each target correctly identified and prosecuted, and subtracting 100 points for each target misidentified or prosecuted incorrectly. Points are also subtracted for each target that crossed a defensive perimeter over the course of the trial (10 points for all intrusions during training and near transfer; 175 points for inner intrusions and 125 points for outer intrusions during far transfer).

In addition to examining overall score, basic and strategic performance composites were created to allow an examination of the relative impact of the manipulations and training processes on different dimensions of skill-based performance. Indicators of a trainee's basic performance are the number of points a trainee gained for correct decisions and the number of points the trainee lost for incorrect decisions. These are the two main components of a trainee's score. In terms of strategic performance, the number of times participants zoomed out and the number of marker targets hooked serve as indicators of situational assessment. Target prioritization was assessed by the number of high priority targets (those targets that are both moving fast and near a perimeter) prosecuted.

Previous research using this task (e.g., Bell & Kozlowski, in press) has shown that these indicators load cleanly onto separate basic and strategic performance components. In the current study, principal components factor analysis using varimax rotation revealed

the same pattern.² To create the composites, the performance measures were standardized within training block and then summed using unit weights. The basic performance composite was created by combining points correct and points incorrect. The strategic performance composite was created by combining the total number of times the trainee zoomed out, the number of marker targets hooked, and the number of high priority targets prosecuted. All indicators were given a positive weight except for points incorrect, which was given a negative weight similar to how it is used to calculate the overall score value.

RESULTS

The categorical nature of the manipulations would suggest using multivariate analysis of covariance (MANCOVA) to analyze the data collected in the current study. However, because I expect the manipulations to interact with several of the individual differences that also serve as control variables, MANCOVA is inappropriate. These interactions would require a different adjustment of dependent variables for covariates in different groups. Thus, these interactions violate the homogeneity of regression assumption and make MANCOVA an inappropriate analytic strategy. An alternative would be to test the hypotheses using analysis of variance without controlling for the individual differences; however, this would prevent an examination of the relative impact of the individual differences and it would not be possible to determine the impact of the error training elements over and above the individual differences. In addition, analysis of variance would prevent an examination of the interactive effects of the error training elements and individual differences. These issues are critical for understanding the factors that influence the effectiveness of error training and active learning more generally.

The hypotheses in the current study, therefore, were tested using hierarchical regression analyses (Cohen & Cohen, 1983). One limitation, however, associated with conducting multiple regression analyses is the potential for an inflated experimentwise Type I error rate. Therefore, a multivariate analysis of variance (MANOVA) was used to provide an initial examination of the overall effect of each error training element on the training processes and outcomes.³ Although MANOVA is not appropriate for testing specific hypotheses in the current study, it is a useful tool for determining the overall

effect of the error training elements. MANOVA tests for overall effects of independent variables on a linear combination of the dependent variables, thereby providing an indication of whether each independent variable had a significant impact on the outcomes examined. In addition to testing for overall effects, MANOVA provides control over inflated familywise Type I error rates that can result from multiple univariate tests (e.g., Haase & Ellis, 1987; Leary & Altmaier, 1980; Tabachnick & Fidell, 1996). Thus, a significant overall effect for an independent variable in MANOVA provides some evidence that it is appropriate to conduct follow-up univariate tests to examine specific relationships. This is not to say that Type I error is eliminated from follow-up univariate tests, but a significant overall effect increases the confidence that can be placed on significant, univariate relationships. The individual differences were not controlled in this analysis to avoid violating the homogeneity of regression assumption and, therefore, the magnitude of these results should be interpreted cautiously.

Using Wilk's lambda, the results of the MANOVA revealed that the instructional element had a significant overall effect on the combined DV's, $F(24, 319) = 9.06, p < .01$, and the emotional element had a marginally significant overall effect $F(24, 319) = 1.43, p < .10$. Although the motivational element had a significant effect on several of the performance outcomes, it did not have a significant overall effect on the combined dependent variables. However, there was a significant overall effect for the interaction of the instructional and motivational elements, $F(24, 319) = 1.80, p < .05$. Finally, the results revealed a non-significant overall effect for the interaction of the instructional and emotional elements as well as the interaction of the motivational and emotional elements. Based on these results, it was deemed appropriate to use regression analyses to examine

the main effects of the three error training elements and the interactive effect of the instructional and motivational elements. The motivational element is included in order to further explore its effects on the performance outcomes and also to partial its linear effects from the instruction x motivation interaction. However, because the overall effect of the motivational element was nonsignificant, any main effects for the motivational element should be interpreted with caution. Due to the nonsignificant overall effects of the instruction x emotion and motivation x emotion interactions, Hypotheses 21 and 22 were deemed as unsupported and these interactive terms were not included in the hierarchical regression analyses.

The hierarchical regression analyses were performed in several stages. First, a series of hierarchical regression analyses were conducted to determine the main and interactive effects of the error training elements on the processes and outcomes examined in the current study. In the first step of these analyses, relevant individual differences were entered to determine their impact on the training process or outcome being examined. Because each of the individual differences assessed in the current study could potentially impact trainees' knowledge and performance, all individual differences were included in the first step of the analyses that examined the effects of the error training elements on individuals' knowledge and performance. However, in an attempt to preserve valuable degrees of freedom and focus the analyses, reduced sets of individual differences were used in those analyses that examined the effects of the error training elements on the instructional, motivational, and emotional processes.⁴ Decisions about which individual differences to include in particular sets of analyses were based on past research as well as expected interactions between the error training elements and

individual differences. Controlling for these variables allows for a more stringent test of the effects of error training elements and also provides an indication of how the various individual differences influence the instructional, motivational, and emotional active learning processes. In the second step, the error training element or elements predicted to influence the outcome were entered to test specific hypotheses. When relevant, the interaction between the instructional and motivational elements was entered in the final step to determine the joint effect of these two elements on the training processes and outcomes. The variables included in each set of analyses are summarized in Table 3.

The second set of regression analyses examined the interactive effects of the manipulations and individual differences on relevant processes and outcomes. Once again the individual differences were entered in the first step and the error training elements were entered in the second step. In the third and final step, interactions between the individual differences and training elements were entered. Separate analyses were conducted for each individual difference. The interactive effects of the manipulations and individual differences on knowledge and performance as well as relevant process variables were examined. Given the number of variables assessed in this study, not all potential interactions or relationships were examined. Rather, decisions about which interactions to explore and on which processes and outcomes were driven by the hypotheses specified earlier.

Based on the findings of these first two series of analyses, a final set of analyses was conducted to test the conceptual model presented in Figure 1. Conducting these tests last allows for a more precise and direct test of the specified relationships. Variables prior to or concurrent with variables in the model were entered to control for the effects

of all other factors when assessing the hypothesized relationships. This set of analyses allowed for a test of the mediational effects implied by the conceptual model but not formally hypothesized.

Although the process variables were assessed both early and later in training, the analyses described above focus primarily on the end of training measures. This strategy was deemed appropriate given the desire to test for mediation, the retrospective nature of many of the process variable measures, and also the proximity of the end of training measures to the measures of transfer performance. Using only measures collected later in training is consistent with several other studies that have employed similar path models (e.g., Ford et al., 1998; Smith, 1996). I will, however, periodically discuss findings observed earlier in training. These findings will be noted when (1) there is strong theoretical reason to expect effects early in training (e.g., such as in the case of state anxiety or cognitive effort) and (2) a particularly noteworthy or meaningful finding is revealed early in training.

The means, standard deviations, and intercorrelations among all variables included in the analyses described below are provided in Table 4. In the sections that follow, I first discuss the results for the manipulation checks that were used in the current study. I then present the results for the regression analyses that examined the main and interactive effects of the error training elements on the training processes and outcomes examined in the current study. Next, I review the results of the regression analyses that explored interactions between the error training elements and individual difference variables. Finally, I present the results of the regression analyses used to test the conceptual model presented in Figure 1.

Manipulation Checks

At the end of training, participants in the proceduralized instruction condition answered the question “I followed the step-by-step instructions given to me for each trial” on a 5-point Likert scale ((1) strongly disagree to (5) strongly agree). The results showed that 81.4% of the participants in the proceduralized instruction condition responded “agree” or “strongly agree” to this item. In addition, analyses revealed that the nature of instruction had a significant effect on the number of errors trainees made during training $F(1, 345) = 101.51, p < .01$.⁵ As expected, exploratory learning led to more errors than proceduralized instruction.

At the end of training, all participants answered two questions designed to check the motivational manipulation: “I tried to make errors as I practiced the simulation” and “I tried to avoid errors as I practiced the simulation.” Both items were rated on a 5-point Likert scale ((1) strongly disagree to (5) strongly agree). The results revealed that participants who received the error encouragement instructions, as compared to the error avoidance instructions, were more likely to indicate that they tried to make errors ($t = 12.24, p < .01$) and less likely to indicate that they tried to avoid errors ($t = -9.52, p < .01$). Additionally, participants given error encouragement directions made more errors during training than individuals given error avoidance directions $F(1, 345) = 3.96, p < .05$.

Finally, all participants answered the question “I made a conscious effort to control my emotions during training” on a 5-point Likert scale ((1) strongly disagree to (5) strongly agree). The results revealed that participants who received the emotion-control training were more likely indicate that they consciously monitored their emotions

during training ($t = 2.65, p < .01$). In addition to teaching individuals how to monitor and control their emotions, the emotion-control training provided participants with statements designed to increase self-confidence and reduce anxiety and frustration. These emotion-control statements were presented on a whiteboard in the training room and on the final page of feedback in six of the training trials. Analysis of the average time individuals spent on these six final feedback screens revealed that individuals in the emotion-control condition spent significantly more time per final feedback screen ($t = 2.34, p < .05$).⁶ These results demonstrate that individuals in the emotion-control condition were exposed to (e.g., read) the emotion-control statements.

In the following sections, I review the results of the regression analyses that examined the direct and interactive effects of the three error training elements on the various training processes and outcomes measured in the current study. I begin with the effects of the instructional manipulation, then I discuss the results for the motivational manipulation, and finally I discuss the findings for the emotion manipulation.

Effects of Instructional Element

Overall performance. Table 5 presents the results of the hierarchical regression analyses examining the effect of the error training elements on trainees' overall performance. As would be expected, cognitive ability had a significant and positive impact on overall performance at the end of training ($\beta = .297, p < .01$) as well as during the near transfer trial ($\beta = .278, p < .01$) and the far transfer trial ($\beta = .428, p < .01$). In general, the other individual differences did not have strong or consistent direct effects on overall performance. Trait anxiety had a marginally significant negative effect on overall performance at the end of training ($\beta = -.096, p < .10$), trait learning orientation had a

positive effect on overall performance in the near transfer trial ($\beta = .123, p < .05$), and performance-prove orientation had a significant, positive effect on overall performance in the far transfer trial ($\beta = .109, p < .05$).

Trainees who received the exploratory instruction displayed significantly lower levels of overall performance in the last training trial ($\beta = -.169, p < .01$). This is expected given that trainees in the proceduralized condition received step-by-step instructions designed to help them avoid mistakes and perform well. As can be seen in Table 5, the instructional element did not have a significant effect on overall performance in the near transfer trial ($\beta = .086, ns$), although trainees who received exploratory instruction performed slightly better. Analyses also revealed that exploratory instruction led to higher levels of overall performance on the far transfer trial ($\beta = .120, p < .05$). However, the instructional element did not interact with the motivational element to significantly influence overall performance during any of the three trials.

Figure 2 presents the standardized means for overall performance for trainees who received exploratory and proceduralized instruction. This figure shows that although trainees who received exploratory instruction exhibited lower levels of performance during training, they performed better on the transfer trials. Essentially, this figure demonstrates the cross-over effect discussed by a number of researchers (Ford & Weissbein, 1997; Mayer & Greeno, 1972; Schmidt & Bjork, 1992) – that is, doing less well during training may have benefits during transfer. Moreover, the benefits associated with exploratory instruction were greatest on the far transfer trial, which is consistent with the idea that active learning techniques are best suited for developing adaptive skills and helping individuals to recognize and respond to changes in task conditions.

Components of performance. Table 6 presents the regression results for analyses that examined the impact of the error training elements on basic and strategic performance during the two transfer trials. Consistent with the findings for overall performance, cognitive ability had a significant and positive impact on trainees' basic performance during both the near ($\beta = .264, p < .01$) and far ($\beta = .387, p < .01$) transfer trials as well as on strategic performance during the near ($\beta = .358, p < .01$) and far ($\beta = .352, p < .01$) transfer trials. Trait learning orientation also had a marginally significant positive impact on basic performance in the near transfer trial ($\beta = .114, p < .10$).

Findings from past research suggest that exploratory learning may produce the largest performance gains on more complex or strategic task components (e.g., Clark & Voogel, 1985; Dormann & Frese, 1994; Frese et al., 1991). Thus, Hypothesis 1 predicted while the nature of instruction should not have a significant effect on overall performance in near transfer, exploratory learning may produce some gain on the more strategic aspects of the task. The results showed that the instructional element did not have a significant effect on basic or strategic performance during near transfer. Thus, it appears that exploratory learning and proceduralized instruction do not produce differences in near transfer performance, regardless of the types of skills being examined.

The greatest advantage of exploratory learning lies in its ability to facilitate the development of generalizable skills. Therefore, Hypothesis 3 predicted that exploratory learning would lead to higher levels of performance in the far transfer, or generalization, trial than proceduralized instruction. In addition, it was argued that this difference would be most pronounced on the more complex and strategic aspects of the transfer task. It was found that individuals who received exploratory instruction displayed higher levels

of both basic performance ($\beta = .114, p < .05$) and strategic performance ($\beta = .097, p < .10$) in the far transfer trial. It is important to note that these effects are of essentially the same magnitude. This suggests that the effects of exploratory learning on performance are not so much contingent on the complexity of the task or skills involved, but rather are driven by the extent to which performance depends on the ability to adapt or generalize one's knowledge and skills. Thus, Hypothesis 3 was supported.

An interesting finding that emerged in follow-up analyses is that trainees who received exploratory instruction prosecuted a significantly greater number of targets in both the near transfer trial ($\beta = .199, p < .01$) and the far transfer trial ($\beta = .147, p < .01$). This suggests that exploratory instruction, as compared to proceduralized instruction, helped individuals to learn how to work faster and more efficiently. In addition, analyses showed that this increase in efficiency was not associated with lower accuracy. Trainees who received exploratory and proceduralized instruction did not significantly differ in the percentage of targets they engaged correctly in the near transfer trial ($\beta = .077, ns$), and trainees who received exploratory instruction actually engaged a greater percentage of their targets correctly in the far transfer trial ($\beta = .119, p < .05$).

Knowledge. Table 7 displays the results of the regression analyses examining the effect of the error training elements on individuals' basic and strategic knowledge at the end of training. In terms of the effect of the individual difference variables, cognitive ability had a significant and positive effect on both basic ($\beta = .331, p < .05$) and strategic ($\beta = .368, p < .05$) knowledge. Trait learning orientation also had a significant and positive effect on basic knowledge ($\beta = .149, p < .05$).

Hypothesis 2 predicted that exploratory instruction would lead to higher levels of knowledge than proceduralized instruction. Furthermore, it was predicted that this difference would be greatest for more complex or strategic knowledge. The analyses revealed that the instructional element did not have a significant direct effect on either basic knowledge ($\beta = .057$, ns) or strategic knowledge ($\beta = .041$, ns) at the end of training. Hypothesis 2 was therefore unsupported. Analyses did reveal a significant direct effect for the instructional element on strategic knowledge early in training ($\beta = -.229$, $p < .01$). Contrary to expectations, individuals who received exploratory instruction displayed lower levels of strategic knowledge. Because the proceduralized instructions provided individuals with support on the more basic aspects of the task early in training, it is likely that these individuals moved more quickly to focusing attention on the more strategic material in the task manual, thereby leading to higher levels of strategic knowledge early in training. By the end of training, individuals in the exploratory condition were able to catch up and actually displayed slightly higher levels of strategic knowledge.

Although the instructional element did not have a significant direct effect on knowledge, there was a marginally significant interaction between the instructional and motivational element on basic knowledge at the end of training ($\beta = .153$, $p < .10$). The nature of this interaction is displayed in Figure 3. As predicted by Hypothesis 20, the nature of the error instructions had the biggest impact when individuals received exploratory instruction. Also, as would be expected, the greatest level of basic knowledge was exhibited by individuals who received both exploratory instruction and error encouragement. Analyses revealed that individuals who received exploratory

instruction and error encouragement had significantly higher levels of basic knowledge than individuals who received proceduralized instruction and error encouragement ($t = -2.54, p < .05$) or exploratory instruction and error avoidance instructions ($t = -1.93, p < .10$). Individuals who received proceduralized instruction and error avoidance directions also displayed lower levels of basic knowledge than individuals who received exploratory instruction and error encouragement, but this difference was not significant. Combined, these results suggest that exploratory instruction and error encouragement had a synergistic effect on basic knowledge; when paired together they led to increased levels of basic knowledge, but when they were paired with an inconsistent training element (proceduralized instruction or error avoidance instructions) there was no gain in knowledge.

Hypothesis-testing. Table 8 presents the results of the hierarchical regression analyses that examined the impact of the individual differences and error training elements on the various cognitive training processes examined in this study. Analyses revealed that a number of the individual differences were related to trainees' hypothesis-testing activities. Hypothesis-testing was significantly and positively related to both conscientiousness ($\beta = .168, p < .01$) and openness to experience ($\beta = .188, p < .01$). In addition, there was a marginally significant, positive relationship between learning orientation and hypothesis-testing ($\beta = .113, p < .10$). Contrary to Hypothesis 4a, however, the nature of the instruction trainees received did not have a significant impact on trainees' hypothesis-testing activities ($\beta = .055, ns$).

Metacognitive Activity. As would be expected, the results revealed that metacognitive activity was significantly and positively related to learning orientation ($\beta =$

.152, $p < .05$), openness to experience ($\beta = .157$, $p < .01$) and conscientiousness ($\beta = .122$, $p < .05$). Perhaps unexpectedly, the results revealed that metacognitive activity exhibited a marginally significant, negative relationship with cognitive ability ($\beta = -.100$, $p < .10$). Hypothesis 5a predicted that trainees who received exploratory instruction would display higher levels of metacognitive activity than trainees given proceduralized instruction. Consistent with expectations, the results revealed a significant and positive effect for exploratory instruction on metacognitive activity ($\beta = .148$, $p < .01$). This suggests that trainees allowed to explore the task and make errors engaged in more self-monitoring and self-evaluation of their progress through training than individuals who received proceduralized instruction. Thus, Hypothesis 5a was supported.

Cognitive effort. As would be expected, cognitive effort exhibited a significant, negative relationship with cognitive ability ($\beta = -.119$, $p < .05$). Also, the results revealed that there was a marginally significant, positive relationship between cognitive effort and openness ($\beta = .113$, $p < .10$) and performance-prove orientation ($\beta = .112$, $p < .10$). Hypothesis 6a predicted that individuals who received the exploratory instruction would display higher levels of cognitive effort than individuals given step-by-step instruction during training. Consistent with this hypothesis, the results revealed that exploratory instruction led to higher levels of cognitive effort than proceduralized instruction ($\beta = .472$, $p < .01$). Thus, Hypothesis 6a was supported. It is worth noting that trainees who received exploratory instruction put forth more cognitive effort early in training as well ($\beta = .101$, $p < .10$), but clearly the difference in effort displayed by those in the exploratory and proceduralized instruction conditions was not nearly as large early in training. Early in training there was also a significant interaction between the

instructional and motivational elements on trainees' cognitive effort ($\beta = .214, p < .05$). This interaction is presented in Figure 4. The difference in cognitive effort linked to the nature of the error directions was similar across the two instructional conditions. Once again, however, we see that the combination of exploratory instruction and error encouragement had a synergistic, positive effect. Individuals who received exploratory instruction and error encouragement displayed significantly higher levels of cognitive effort early in training than individuals who received exploratory instruction and error avoidance directions ($t = -2.03, p < .05$) and individuals who received proceduralized instruction and error encouragement ($t = -3.32, p < .01$). They also displayed higher levels of cognitive effort than individuals who received proceduralized instruction and error avoidance directions, although the difference was only marginally significant ($t = -1.74, p < .10$).

Self-evaluation activity. Table 8 shows that none of the individual differences influenced individuals' self-evaluation activity. Contrary to expectations, the instructional element did not have a significant effect on individuals' self-evaluation activity ($\beta = .038, ns$). However, there was a significant interaction between the instructional and motivational elements on self-evaluation ($\beta = .228, p < .05$). This interaction is presented in Figure 5. Once again, the most positive effects are observed among those individuals who received exploratory instruction and error encouragement. However, Figure 5 shows that individuals who received proceduralized instruction and error avoidance directions displayed similar levels of self-evaluation activity. Thus, it appears that this interaction is best described as a consistency effect in which individuals who received exploratory instruction and error encouragement or proceduralized

instruction and error avoidance displayed the most self-evaluation activity. It may be that individuals in the other conditions became confused by the mixed messages sent by the conflicting training instructions and therefore were not sure what they should be monitoring or using to evaluate their progress.

Intrinsic motivation. The final set of predictions concerns the impact of the instructional element on intrinsic motivation. Table 9 presents the results of the hierarchical regressions that examined the impact of the individual differences and error training elements on motivational factors. As can be seen in Table 9, intrinsic motivation was significantly and positively related to trainees' learning orientation ($\beta = .117, p < .10$). Otherwise, the individual differences did not have a significant relationship with intrinsic motivation.

Hypothesis 7a argued that exploratory instruction would lead to higher levels of intrinsic motivation than proceduralized instruction. While the instructional element did not exhibit a significant direct effect on intrinsic motivation ($\beta = .057, ns$), it did interact with the nature of the error instructions to significantly influence trainees' intrinsic motivation ($\beta = -.191, p < .05$). This interaction is displayed in Figure 6. This figure shows that, as expected, individuals who received proceduralized instruction and were directed to avoid errors reported the lowest level of intrinsic motivation. Individuals in this condition reported significantly less intrinsic motivation than individuals who received proceduralized instruction and error encouragement ($t = -1.875, p < .10$) and individuals who received exploratory instruction and error avoidance directions ($t = -2.30, p < .05$). Surprisingly, although individuals who received exploratory instruction and error encouragement reported more intrinsic motivation than individuals who

received proceduralized instruction and error avoidance directions, these two groups did not significantly differ from one another. It should be noted that the same interaction emerged early in training, and in both cases the three groups other than the proceduralized-error avoidance group did not differ significantly from one other.

Summary. Below, I briefly summarize the key findings for the instructional element reported in the preceding sections:

1. Trainees who received exploratory instruction exhibited significantly lower levels of overall performance during training. However, they performed slightly better than the proceduralized group in the near transfer trial and significantly better in far transfer trial.
2. Results for basic and strategic performance suggest that the benefits of exploratory learning are linked to the extent that knowledge and skills must be generalized, not the complexity of the knowledge and skills.
3. Exploratory learning led to significantly lower levels of strategic knowledge early in training. The instructional and motivational elements interacted to significantly influence basic knowledge at the end of training. The highest level of knowledge was observed among those that received both exploratory instruction and error encouragement directions.
4. The instructional element did not influence the extent to which individuals engaged in hypothesis-testing activities. However, individuals who received exploratory instruction exhibited higher levels of metacognitive activity and cognitive effort at the end of training.
5. The effect of the instructional element on cognitive effort early in training, self-evaluation activity, and intrinsic motivation was contingent on the nature of the motivational element. In general, the most positive outcomes were found when individuals received both exploratory instruction and error encouragement directions. Only in the case of intrinsic motivation was there any benefit to combining proceduralized instruction and error encouragement or exploratory instruction and error avoidance.

Effects of Motivational Element

Overall performance. The first set of analyses for the motivational element examined the effects of error encouragement and error avoidance directions on trainees'

overall performance. The results revealed that the motivational element did not have a significant impact on individuals' overall performance at the end of training ($\beta = .003$, ns) or in the near transfer trial ($\beta = .012$, ns). However, individuals who received error encouragement instructions exhibited higher levels of performance on the far transfer or generalization trial than trainees who received error avoidance instructions ($\beta = .102$, $p < .05$). Similar to the instructional element, these results suggest that the benefits of error encouragement emerge when individuals must adapt what they have learned in training to a novel context. When the nature of the performance environment was consistent with the training environment, error encouragement and error avoidance instructions led to similar levels of performance. However, the error encouragement instructions appear to have facilitated individuals' ability to generalize their skills in the far transfer trial.

Performance components. Due to the fact that most previous research on error encouragement has used relatively proceduralized tasks (e.g., word-processing or spreadsheet programs), it was difficult to hypothesize differential effects of the motivational element on different types of performance. Thus, Hypothesis 8 predicted that error encouragement would lead to higher levels of both basic and strategic near transfer performance. As can be seen in Table 6, some support was found for this hypothesis. The motivational element did not have a significant effect on basic performance in near transfer, but did have a marginally significant, positive effect on strategic performance in the near transfer trial ($\beta = .087$, $p < .10$). Thus, Hypothesis 8 was partially supported.

Hypothesis 10 predicted that error encouragement would also lead to higher levels of both basic and strategic performance in far transfer. Analyses revealed a marginally

significant, positive effect of error encouragement on both basic ($\beta = .087, p < .10$) and strategic performance ($\beta = .097, p < .10$) in far transfer. Thus, Hypothesis 10 was supported.

Consistent with the effects for overall performance, these results suggest that error encouragement is particularly beneficial when individuals are asked to generalize their skills to a novel and more complex environment. In addition, it appears that error encouragement enhanced trainees' ability to perform well on the more complex, strategic task components, regardless of whether the performance environment was similar to or different from the training environment.

Knowledge. Hypothesis 9 predicted that the motivational element would have a significant influence on individuals' basic and strategic knowledge. The motivational element did not have a significant direct effect on individuals' basic ($\beta = .011, ns$) or strategic knowledge ($\beta = .002, ns$). Thus, hypothesis 9 was unsupported. As discussed above, however, there was a significant interaction between the instructional and motivational elements on individuals' basic knowledge. The nature of this interaction, shown in Figure 3, suggests that error encouragement leads to higher levels of basic knowledge only when combined with exploratory instruction. Thus, it appears that the effect of the error instructions on basic knowledge is contingent on the nature of the instructional environment.

State goal orientation. Table 9 presents the results of the hierarchical regression analyses that examined the effects of the individual differences and error training elements on state goal orientation. As would be expected, state performance-avoid orientation was significantly and positively related to trait performance-avoid orientation

($\beta = .194, p < .01$), trait performance-prove orientation ($\beta = .192, p < .01$) and trait anxiety ($\beta = .250, p < .01$). In addition, there was a significant, negative relationship between performance-avoid orientation and trait learning orientation ($\beta = -.138, p < .05$). Contrary to Hypothesis 11, the motivational manipulation did not have a significant direct effect on state performance-avoid orientation ($\beta = -.006, \text{ns}$) nor did it interact with the instructional manipulation to influence state performance-avoid orientation ($\beta = .080, \text{ns}$).

State learning orientation was positively related to trait learning orientation ($\beta = .311, p < .01$) and conscientiousness ($\beta = .157, p < .01$). In addition, state learning orientation exhibited a marginally significant, negative relationship with trait performance-avoid orientation ($\beta = -.103, p < .10$). The motivational manipulation, however, did not have a significant direct ($\beta = .064, \text{ns}$) or interactive ($\beta = .086, \text{ns}$) effect on state learning orientation.

Finally, state performance-prove orientation was positively related to only trait performance-prove orientation ($\beta = .428, p < .01$). The motivational element did not have a significant direct ($\beta = -.001, \text{ns}$) or interactive ($\beta = -.050, \text{ns}$) effect on state performance-prove orientation.

Overall, the motivational element did not have a significant effect on trainees' state goal orientation and Hypothesis 11 was therefore unsupported. As we will discuss later, however, analyses did reveal significant interactions between the motivational element and trait goal orientation on individuals' state goal orientation.

Intrinsic motivation. Although not formally hypothesized, the motivational element was predicted to influence trainees' intrinsic motivation through its effects on

state goal orientation. The motivational manipulation did not have a significant, direct effect on intrinsic motivation ($\beta = .032$, ns). As noted earlier, however, the instructional and motivational elements interacted to significantly influence intrinsic motivation ($\beta = -.191$, $p < .05$). Individuals who received proceduralized instruction and error avoidance directions displayed the lowest levels of intrinsic motivation. The other three groups reported similar levels of intrinsic motivation.

Self-efficacy. The motivational element was also predicted to influence individuals' self-efficacy through its effects on state goal orientation. Table 9 shows that self-efficacy was significantly and positively related to trait learning orientation ($\beta = .206$, $p < .01$) and performance-prove orientation ($\beta = .126$, $p < .05$). In addition, self-efficacy was negatively related to both trait anxiety ($\beta = -.199$, $p < .01$) and performance-avoid orientation ($\beta = -.107$, $p < .10$). Contrary to expectations, the motivational element did not exhibit a significant direct ($\beta = .064$, ns) or interactive ($\beta = -.027$, ns) effect on trainees' self-efficacy.

State anxiety. Finally, the motivational manipulation was expected to influence individuals' state anxiety through its effects on state goal orientation. The results for the emotional processes are displayed in Table 10. As would be expected, state anxiety was significantly and positively related to trait anxiety ($\beta = .281$, $p < .01$). However, the motivational element did not have a significant direct effect on trainees' state anxiety ($\beta = -.025$, ns).

Summary. Below, I briefly summarize the key findings for the motivational element discussed in the preceding sections:

1. During training and near transfer, trainees who received error encouragement directions exhibited similar levels of overall performance as trainees who received error avoidance directions. However, error encouragement led to higher levels of overall performance in the far transfer trial.
2. Results for basic and strategic performance showed that error encouragement led to higher levels of strategic performance on both the near and far transfer trials and higher levels of basic performance in far transfer. This suggests that error encouragement may be well suited for developing both complex or strategic skills as well as adaptability.
3. Error encouragement did not have a significant direct effect on knowledge, but did interact with the instructional element to influence basic knowledge at the end of training. Error encouragement led to higher levels of basic knowledge when paired with exploratory learning.
4. The motivational element did not have a significant direct effect on state goal orientation, but did interact with the instructional manipulation to influence intrinsic motivation. Error avoidance led to the lowest level of intrinsic motivation when paired with proceduralized instruction, but led to higher levels of intrinsic motivation when paired with exploratory instruction. Error encouragement led to relatively high levels of intrinsic motivation when paired with both exploratory and proceduralized instruction.

Effects of Emotional Element

Performance. Hypotheses 15 and 17 predicted that individuals who received emotion-control training would outperform individuals who did not receive any emotion-control training on the near and far transfer trials, respectively. Contrary to expectations, the emotional element did not have a significant effect on individuals' overall performance during training ($\beta = -.017$, ns) or in the near ($\beta = -.010$, ns) or far ($\beta = -.028$, ns) transfer trials. Similar results emerged when performance was broken down into the basic and strategic composites, although individuals who received the emotion-control training displayed lower levels of strategic performance during near transfer ($\beta = -.109$, $p < .05$). Although the effects of the emotional element on performance were generally non-significant, it should be noted that the general pattern was that individuals who

received emotion-control training exhibited lower levels of performance. Thus, Hypotheses 15 and 17 were not supported.

Knowledge. Hypothesis 16 predicted that trainees who received the emotion-control training would display higher levels of task knowledge. Contrary to expectations, the emotional element did not significantly influence individuals' basic ($\beta = -.043$, ns) or strategic ($\beta = -.085$, ns) knowledge at the end of training. It should be noted that there was a marginally significant, negative impact for the emotion-control training on individuals' basic ($\beta = -.096$, $p < .10$) and strategic ($\beta = -.090$, $p < .10$) knowledge early in training. Combined with the results for performance, these findings suggest that the emotion-control training may have limited individuals' ability to learn the training material and perform well. One potential explanation is that the emotion-control training led to cognitive overload and reduced individuals' ability to focus on the training material. It is not surprising that these effects were most pronounced early in training, because it is then that cognitive load is highest and training elements that distract from a task-based focus are likely to have a negative impact (Kanfer & Ackerman, 1989). Unfortunately, it is also early in training that individuals are most likely to experience anxiety and frustration and emotion-control may be most crucial.

State anxiety. Table 10 displays the results of the analyses that examined the effects of the individual differences and error training elements on the emotional training processes assessed in the current study. Consistent with Hypothesis 18, the emotion-control training had a marginally significant, negative effect on state anxiety at the end of training ($\beta = -.095$, $p < .10$). It is important to note that the emotion-control training also led to lower levels of state anxiety early in training ($\beta = -.136$, $p < .01$). The effect of the

emotion-control training on state-anxiety was more pronounced earlier in training, which is consistent with the idea that emotion-control interventions are likely to be most influential early in training when individuals are more likely to experience stress and anxiety as they struggle to learn the task and perform well (Kanfer & Heggestad, 1999).

Feeling of control. Hypothesis 19a predicted that the emotion-control training would have a positive influence on individuals' feelings of control. The results revealed a significant relationship between feelings of control and trait learning orientation ($\beta = .170, p < .05$). Also, feelings of control exhibited a significant and negative relationship with trait anxiety ($\beta = -.140, p < .05$). Contrary to expectations, the emotion-control training did not have a significant effect on feelings of control ($\beta = -.006, ns$). Thus, Hypothesis 19a was unsupported.

Additional results. Additional, exploratory analyses revealed several findings surrounding the emotional element that are worth noting. First, the emotion-control training had a marginally significant, negative effect on trainees' self-evaluation activities at the end of training ($\beta = -.091, p < .10$). This may help to explain why individuals who received the emotion-control training displayed somewhat lower levels of performance. This finding supports the notion that encouraging individuals to monitor and control and their emotions detracted from the attention they focused on the task and their training progress. Analyses revealed that the emotion-control training had a significant and positive effect on trainees' self-efficacy early in training ($\beta = .160, p < .01$). This finding is consistent with the fact that the emotion-control statements encouraged individuals to maintain a positive "can do" attitude and believe that they could do well. Figure 7 shows the mean levels of self-efficacy early and later in training for individuals who did and did

not receive emotion-control training. As can be seen in Figure 7, the emotion-control training gave individuals an initial boost in self-efficacy early in training that they essentially maintained across training. By the end of training, individuals who did not receive emotion-control training had a similar, but still slightly lower, level of self-efficacy.

Summary. In the following sections, I briefly review the findings for the emotional element presented in the preceding sections:

1. The emotional element did not have a significant effect on overall performance during training or in the near and far transfer trials.
2. Trainees who received the emotion-control training displayed lower levels of strategic performance during near transfer.
3. The emotional element had a marginally significant, negative effect on basic and strategic knowledge early in training. Combined with the effects for strategic performance, these results suggest that focusing individuals on monitoring and controlling their emotions may have led to cognitive overload or may have reduced the attention these individuals focused on the task.
4. Individuals who received the emotion-control training reported significantly lower levels of state anxiety. This effect was greatest early in training.
5. The emotional element did not significantly influence individuals' feelings of control.
6. The emotion-control training led individuals to engage less in self-evaluation at the end of training and led to higher levels of self-efficacy early in training.

Aptitude x Treatment Interactions

While the primary goal of this study was to decompose and analyze the instructional, motivational, and emotional elements of error training, a secondary objective was to explore several individual differences as potential moderators of the effects of these different elements. There is emerging literature to suggest that individual

differences, such as cognitive ability, conscientiousness, and openness to experience, may moderate the relationship between active learning techniques and important training processes and outcomes (e.g., Gully et al., 2002). Thus, the current study explored interactions between the error training elements and cognitive ability, conscientiousness, openness to experience, trait goal orientation, and trait anxiety. The goal was to attempt to replicate several findings that have recently appeared in the literature as well as to examine several additional potential interactive effects.

In the sections below, I discuss the interactive effects of the error training elements with these various individual differences. For each set of interactions, initial analyses examined whether there were interactive effects on knowledge and performance. If such interactions were supported, additional analyses were conducted to examine whether the interactions influenced relevant process variables. This analysis plan not only provides an indication of the general nature of the interaction but also makes it possible to determine the processes by which the interaction may have its effects on trainees' knowledge and performance. The results from these analyses will be used in later analyses to explore the potential for mediated moderation effects.

Significant interactions were plotted using the techniques described by Aiken and West (1991) to provide insight into the nature of the interactive relationships. Simple slope tests were also performed to provide an indication of whether the relationship between the individual difference and the outcome was significant within each training condition. Slopes significantly different from zero are indicated by solid lines; slopes not significantly different from zero are noted by dashed lines. Finally, for significant interactions, tests were performed to determine whether predicted values for different

groups (e.g., exploratory and proceduralized instruction) differ at the high (1 SD above the mean) and low (1 SD below the mean) values of the continuous individual difference. These tests were performed using a version of the Johnson-Neyman technique described by Aiken and West (1991, pp. 132-133).

Cognitive ability interactions. Hypotheses 23 and 26 predicted that cognitive ability would interact with the instructional and emotional elements, respectively, to influenced individuals' knowledge and performance. It was predicted that individuals high in ability would benefit more from exploratory instruction than proceduralized instruction, whereas the opposite would be true for individuals low in ability. In addition, I predicted that individuals' low in ability would display higher levels of knowledge and performance when given the emotion-control training, but the emotion-control training would have little effect on the knowledge and performance of high ability trainees. Table 11 presents selected regression results for the analyses that examined the interactive effects of the instructional element and cognitive ability and the emotional element and cognitive ability.

Analyses revealed that the type of instruction interacted with cognitive ability to significantly influence individuals' strategic performance in the generalization trial ($\beta = -.141, p < .05$). This interaction is shown in Figure 8. In both conditions there was a significant and positive relationship between cognitive ability and performance, but effect of cognitive ability was stronger in the proceduralized condition ($\beta = .438, p < .01$) than in the exploratory condition ($\beta = .236, p < .05$). In addition, individuals high in ability (e.g., one SD above the mean) displayed similar levels of strategic performance when given exploratory or proceduralized instruction ($t = -0.07, ns$), but individuals low in

ability (e.g., one SD below the mean) displayed higher levels of strategic performance when given exploratory instruction ($t = 2.79, p < .01$).

A similar interaction emerged between the nature of instruction and cognitive ability on strategic knowledge at the end of training ($\beta = -.171, p < .05$). This interaction is shown in Figure 9. For strategic knowledge, the relationship between cognitive ability and knowledge was significant in the proceduralized instruction condition ($\beta = .376, p < .01$), but not in the exploratory instruction condition ($\beta = .130, ns$). Also, once again individuals high in ability displayed similar levels of strategic knowledge when given exploratory or proceduralized instruction ($t = -1.18, ns$), but individuals low in ability displayed significantly higher levels of strategic knowledge when given exploratory instruction ($t = 2.34, p < .05$). Together, these results for strategic knowledge and performance suggest that exploratory instruction helped individuals low in ability learn the more complex, strategic aspects of the task.

Given the significant interactive effects of the instructional element and cognitive ability on individuals' strategic knowledge and performance, follow-up analyses were conducted to examine whether any significant interactions emerged on the instructional process variables. As can be seen in Table 11, there was a marginally significant interaction for type of instruction and cognitive ability on individuals' metacognitive activity ($\beta = .137, p < .10$). The nature of this interaction is shown in Figure 10. Individuals low in ability displayed similar levels of metacognitive activity when given exploratory or proceduralized instruction ($t = 0.66, ns$), but high ability individuals displayed significantly lower levels of metacognitive activity when given proceduralized instruction ($t = 3.40, p < .01$). Simple slope tests revealed that in the exploratory

instruction condition the relationship between cognitive ability and metacognitive activity was nonsignificant ($\beta = -.010$, ns), but in the proceduralized condition there was a significant, negative relationship between cognitive ability and metacognition ($\beta = -.207$, $p < .01$). This provides additional evidence that exploratory instruction may help to ameliorate the negative effects of low ability. It also suggests that proceduralized instruction was particularly detrimental to the metacognitive activity of high ability individuals. The instructional element did not interact with cognitive ability to significantly influence any of the other instructional process variables (e.g., cognitive effort, hypothesis-testing).

The regression analyses provided only minimal support for interactive effects of the emotion element and cognitive ability on knowledge and performance. As shown in Table 11, the emotional element and cognitive ability significantly interacted to influence only strategic knowledge at the end of training ($\beta = .140$, $p < .05$). The nature of this interaction is shown in Figure 11. Within both conditions there was a significant and positive relationship between ability and strategic knowledge. However, consistent with expectations, individuals high in ability displayed similar levels of strategic knowledge when they received the emotion-control training as when they did not receive emotion-control training ($t = 0.18$, ns). Individuals low in ability, however, displayed higher levels of strategic knowledge when they did not receive the emotion-control training ($t = -2.63$, $p < .01$). Although this is contrary to initial expectations, it helps to explain the earlier finding that emotion-control training led to lower levels of strategic knowledge. I suggested that the emotion-control training may have led to increased cognitive load or distracted individuals from the task, a hypothesis which is supported by the fact that the

emotion-control training only led to lower levels of strategic knowledge among low ability individuals.

Follow-up analyses revealed that the emotional element and cognitive ability did not interact to significantly influence individuals' state anxiety, but there was a significant interactive effect on trainees' feelings of control ($\beta = -.184, p < .05$). As shown in Figure 12, the relationship between cognitive ability and feelings of control was nonsignificant in both conditions. But, the emotion-control training had a marginally significant positive effect on feelings of control among low ability individuals ($t = 1.71, p < .10$) and a marginally significant negative effect on feelings of control among high ability individuals ($t = -1.84, p < .10$). This finding provides further support for the conflicting effects of the emotion-control training. It appears that although the emotion-training impeded the learning and performance of low ability individuals it helped them to feel more in control.

Trait learning orientation interactions. In their recent study on the role of individual differences in error encouragement training, Gully et al. (2001) proposed that error training would be most effective for individuals high in learning orientation and proceduralized instruction would be most appropriate for individuals high in performance orientation. Essentially, they argued that error training may only be effective when it is consistent, or does not contradict, a person's natural orientation. However, their results failed to support these interactions among error training and trait goal orientation. As a result, such interactions were not proposed in the current study.

However, Gully and colleagues utilized a two-dimensional conceptualization of goal orientation and suggested that such interactions may emerge when performance

orientation is divided into separate prove and avoid components. Since the three-dimensional conceptualization of trait goal orientation was used in the current study, the decision was made to explore the potential for interactions among the error training elements and trait goal orientation within the current data.

Analyses were conducted to examine whether trait goal orientation moderated the effects of both the instructional and motivational error training elements. It was expected that a pattern similar to that proposed by Gully would emerge. Specifically, exploratory instruction and error encouragement should be most effective when individuals are high in learning orientation and low in performance-avoid orientation. Alternatively, proceduralized instruction and error avoidance should be most effective when individuals are low in learning orientation and high in performance-avoid orientation. Performance-prove orientation is somewhat more ambiguous because it is driven by both need for achievement and fear of failure. As a result, it can produce complex and variant direct relationships with constructs, which makes it difficult to pose how it would moderate the effects of the instructional and motivational elements.

Table 12 presents selected regression results from analyses that examined the interactive effects of learning goal orientation and the instructional and motivational elements. The analyses revealed that the instructional element interacted with learning goal orientation to significantly influence individuals' strategic performance in the near transfer trial ($\beta = -.124, p < .10$) and the far transfer trial ($\beta = -.143, p < .05$). The nature of this interaction for strategic performance in the far transfer trial is shown in Figure 13. As can be seen in Figure 13, there was a nonsignificant relationship between learning orientation and strategic performance in both instructional conditions. However, whereas

individuals high in learning orientation performed about the same when given exploratory or proceduralized instruction ($t = -0.18$, ns), individuals low in learning orientation performed better when given exploratory instruction ($t = 2.88$, $p < .01$). The interaction of the instructional element and learning orientation on strategic performance in the near transfer trial followed a similar pattern.

Follow-up analyses revealed marginally significant interactions between the instructional element and learning orientation on trainees' hypothesis-testing activities ($\beta = -.124$, $p < .10$), self-evaluation activity ($\beta = -.133$, $p < .10$), and intrinsic motivation ($\beta = -.134$, $p < .10$). Again, these interactions showed that individuals high in learning orientation had similar outcomes regardless of whether they received exploratory or proceduralized instruction. However, individuals low in learning orientation had higher levels of hypothesis-testing activity, self-evaluation activity, and intrinsic motivation when they received exploratory as compared to proceduralized instruction. For example, Figure 14 shows the interaction of type of instruction and learning orientation on hypothesis-testing activity. As depicted in the figure, individuals low in learning orientation displayed significantly higher levels of hypothesis-testing when given exploratory instruction ($t = 2.05$, $p < .05$), but individuals high in learning orientation displayed similar levels of hypothesis-testing activity in both instructional conditions ($t = -0.54$, ns).

The findings above suggest that the exploratory instruction may have been particularly beneficial for individuals low in learning orientation. The nature of the instruction made little difference for individuals high in learning orientation. But, individuals low in learning orientation displayed more positive outcomes when given

exploratory instruction. It may be that the exploratory instruction served to overcome some of the negative learning patterns associated with low levels of learning orientation, while proceduralized instruction exacerbated the negative effects of low levels of learning orientation.

The regression analyses showed that the motivational manipulation did not interact with learning orientation to influence individuals' knowledge or performance. However, it is worth noting that the motivational manipulation interacted with learning orientation to influence individuals' intrinsic motivation ($\beta = -.134, p < .10$) and state performance-prove orientation both early in training ($\beta = -.202, p < .01$) and at the end of training ($\beta = -.175, p < .05$). The nature of each of these interactions was essentially the same. For example, Figure 15 displays the interaction of the motivation element and learning orientation on state performance-prove orientation at the end of training. Individuals low in learning orientation had higher levels of state performance-prove orientation when directed to make errors ($t = 1.78, p < .10$), whereas the individuals high in learning orientation had similar levels of state performance-prove orientation of when given error encouragement and error avoidance directions. Also, the motivational element interacted with learning orientation to significantly influence individuals' state learning orientation early in training ($\beta = -.169, p < .05$). Figure 16 shows the interaction between the motivational element and learning orientation on state learning orientation early in training. As would be expected, there was a significant and positive relationship between trait and state learning orientation in both the error encouragement ($\beta = .206, p < .01$) and error avoidance conditions ($\beta = .443, p < .01$). Also, while not significant, individuals low in learning orientation displayed higher levels of state learning

orientation when given error encouragement directions, whereas individuals high in learning orientation reported similar levels of state learning orientation when given error encouragement and error avoidance directions.

Thus, the nature of the interactions between the motivational manipulation and trait learning orientation were similar to those found between trait learning orientation and the instructional manipulation. Although individuals high in learning were relatively unaffected by the nature of the error instructions, individuals low in learning orientation displayed markedly different outcomes depending on how errors were framed. Error encouragement directions seemed to help overcome some of the drawbacks associated with low levels of trait learning orientation, while error avoidance directions compounded the disadvantages of low learning orientation.

Trait performance-avoid orientation interactions. Table 13 presents selected regression results from analyses that examined the interactive effects of performance-avoid orientation and the instructional and motivational elements. Analyses revealed that the instructional element interacted with individuals' trait performance-avoid orientation to significantly influence basic performance during near transfer ($\beta = -.148, p < .05$). In addition, the type of instruction and performance-avoid orientation displayed marginally significant interactions on trainees' basic knowledge early in training ($\beta = -.118, p < .10$). Figure 17 shows the interaction between the instructional element and trait performance-avoid orientation on individuals' basic performance in the near transfer trial. This figure shows that exploratory instruction led to increased performance for individuals low in performance-avoid orientation ($t = 2.39, p < .05$), but had little effect on the performance of individuals high in avoid orientation ($t = -0.45, ns$). Also interesting is the fact that

avoid orientation was unrelated to basic performance ($\beta = .007, p < .05$) when individuals received proceduralized instruction. The interaction for basic knowledge followed a similar pattern.

The results also revealed a marginally significant interaction between the instructional element and trait performance-avoid orientation on strategic knowledge later in training ($\beta = .133, p < .10$). As shown in Figure 18, this interaction followed a different pattern than the other interactive effects. Avoid orientation was not significantly related to strategic knowledge in either the exploratory or proceduralized instruction conditions. Furthermore, individuals low in avoid orientation displayed similar levels of strategic knowledge when given exploratory and proceduralized instruction ($t = -0.72, ns$). However, individuals high in avoid orientation displayed somewhat higher levels of strategic knowledge when given exploratory rather than proceduralized instruction ($t = 1.92, p < .10$).

Overall, the findings suggest that exploratory learning was more effective for individuals with lower levels of performance-avoid orientation. In addition, avoid orientation tended to be unrelated to knowledge and performance in the proceduralized instruction condition, which suggests that by preventing individuals from making errors the effects of avoid orientation were neutralized. Unfortunately, follow-up analyses did not reveal any significant interactions between the instructional element and performance-avoid orientation on the instructional processes. So, it is difficult to determine the precise causes of these effects on knowledge and performance. Yet, it is clear that exploratory instruction was more effective for individuals with low as compared to high levels of performance-avoid orientation.

The motivational manipulation and trainees' performance-avoid orientation did not interact to significantly influence individuals' knowledge or performance. However, the motivational manipulation interacted with trait-performance avoid orientation to significantly impact individuals' state performance-avoid orientation both early ($\beta = .149$, $p < .05$) and later ($\beta = .129$, $p < .05$) in training. The interaction at the end of training is shown in Figure 19, although the interaction early in training was similar in nature. Similar to the effects for the instructional element, when individuals were told to avoid errors there was a nonsignificant relationship between state and trait avoid orientation ($\beta = .104$, ns) . However, when individuals were told to make errors, there was a positive relationship between trait and state avoid orientation ($\beta = .294$, $p < .01$). Also, while not significant, individuals low in avoid orientation displayed lower levels of state avoid orientation when encouraged to make errors, whereas individuals high in avoid orientation actually displayed higher levels of state avoid orientation when encouraged to make errors. This suggests that error encouragement only led to lower levels of state avoid orientation among individuals low in trait avoid orientation. This provides additional support for the notion that error training may be better suited for individuals low in trait performance-avoid orientation.

Trait performance-prove orientation interactions. Analyses revealed that trait performance-prove orientation did not interact with either the instructional or motivational elements to influence trainees' knowledge or performance. Trait performance-prove orientation also did not interact with either manipulation to influence individuals' state performance-prove orientation. One explanation for this finding is that performance-prove orientation does not correspond well with the nature of the

instructional and motivational manipulations. These two manipulations represent more of a distinction between learning orientation (exploratory instruction and make errors) and performance-avoid orientation (proceduralized instruction and avoid errors).

Openness to experience interactions. Hypothesis 24 predicted that the type of instruction would interact with individuals' openness to experience to influence knowledge and performance. Specifically, it was expected that individuals high in openness to experience would exhibit higher levels of knowledge and performance under exploratory learning than proceduralized instruction, while individuals low in openness would exhibit similar levels of knowledge and performance under both types of instruction. Analyses revealed that openness did not interact with the instructional manipulation to influence individuals' basic or strategic knowledge and performance. As shown in Table 14, however, there was a significant interaction between the type of instruction and openness to experience on the number of targets engaged during the near ($\beta = .145, p < .10$) and far ($\beta = .154, p < .05$) transfer trials. The nature of these interactions was the same. As shown in Figure 20, individuals low in openness to experience prosecuted a similar number of targets regardless of whether they received exploratory or proceduralized instruction ($t = 0.46, ns$). However, individuals high in openness to experience prosecuted a greater number of targets when trained with exploratory instruction rather than proceduralized instruction ($t = 3.39, p < .01$). Also, this increase in efficiency was not associated with reduced accuracy. In fact, individuals who were high in openness to experience and received exploratory instruction displayed the highest levels of accuracy in both the near and far transfer trial, although the

differences were not significant. This finding suggests that exploratory instruction leads to increased efficiency only among individuals high in openness to experience.

Conscientiousness interactions. Hypothesis 25 predicted that the type of error instructions would interact with conscientiousness to influence trainees' knowledge and performance. Specifically, it was expected that individuals high in conscientiousness would have higher levels of knowledge and performance in the avoid errors than the make errors condition; however, individuals low in conscientiousness would have higher levels of knowledge and performance in the make errors than the avoid errors condition. Analyses revealed that the motivational manipulation did not interact with conscientiousness to influence individuals' knowledge or performance and Hypothesis 24, therefore, was unsupported.

One possible explanation for this finding is that it is not the nature of the error directions that evokes different responses from individuals high and low in conscientiousness, but rather the nature of the instruction. Additional analyses, therefore, were conducted to examine whether the instructional element interacted with conscientiousness to influence individuals' knowledge and performance. Only limited support was found for the interactive effects of the instructional element and conscientiousness. These results are presented in Table 15. The instructional element and conscientiousness interacted to significantly influence trainees' basic performance in near transfer ($\beta = .157, p < .05$).

The interaction on basic performance in near transfer is shown in Figure 21. Conscientiousness was essentially unrelated to basic performance in the exploratory condition ($\beta = .018, ns$), but there was a negative relationship between conscientiousness

and basic performance in the proceduralized instruction condition ($\beta = -.216, p < .05$). In addition, individuals low in conscientiousness displayed similar levels of performance in both the exploratory and proceduralized instruction conditions ($t = -0.53, ns$). Contrary to expectations, individuals high in conscientiousness displayed higher levels of basic performance when given exploratory instruction ($t = 2.62, p < .01$). It may be that proceduralized instruction is restricting to individuals who are high in conscientiousness and want to perform well. It may be that these individuals like the freedom offered by exploratory instruction because it allows them to focus on doing well and allows them to practice in the manner that is most effective for them. Unfortunately, the type of instruction did not interact with conscientiousness to influence any of the instructional processes at the end of training and it is, therefore, difficult to gain further insight into this finding.

Trait anxiety interactions. Hypothesis 27 predicted that the emotion-control training would interact with individuals' trait anxiety to influence knowledge and performance. It was suggested that the emotion-control training would produce significant benefits for those high in trait anxiety, but have relatively little impact on the knowledge and performance of those low in trait anxiety. The regression results revealed that the emotion-control training did not interact with trait anxiety to influence trainees' knowledge or performance. Thus, Hypothesis 27 was not supported. It is worth noting, however, that there was a marginally significant interaction between the emotion-control training and trait anxiety on individuals' feelings of control ($\beta = .125, p < .11$). These results are presented in Table 16 and the interaction is shown in Figure 22. As can be seen in the figure, the relationship between trait anxiety and feelings of control was

nonsignificant when individuals received emotion-control training ($\beta = -.065$, *ns*).

However, trait anxiety had a negative effect on feelings of control when individuals did not receive the emotion control training ($\beta = -.233$, $p < .01$). This suggests that the emotion-control training helped to buffer the negative effects of trait anxiety on trainees' performance attributions. In addition, while not significant, the emotion-control training only led to increased feelings of control among individuals high in trait anxiety.

Individuals low in trait anxiety actually displayed decreased feelings of control when given the emotion-control training.

Mediation Analyses

The final set of analyses was designed to test a few remaining aspects of the conceptual model presented in Figure 1. Two primary issues were addressed. First, the relationships between the instructional, motivational, and emotional processes and individuals knowledge and performance were examined. Second, analyses were conducted to determine whether the process variables mediated the effects of the error training elements and individual differences on trainees' knowledge and performance.

As described by Baron and Kenny (1986) and James and Brett (1984), classic mediation requires that four conditions must be met. First, the distal predictors, or antecedents, must be significantly related to the proposed mediators.⁷ This condition has been established in the previous analyses. Second, the distal predictors must significantly influence the outcome variable. Third, the proposed mediators must significantly influence the outcome variable. Finally, the relationship between the distal predictor and outcome variable is reduced (partial mediation) or eliminated (full mediation) after controlling for the effects of the proposed mediators.

The last three mediation conditions were tested using hierarchical regression analyses. In the first step of the regression, cognitive ability was entered to control for its effects on the outcome of interest. Cognitive ability was entered as a control variable rather than as an antecedent because it had a strong influence on knowledge and performance and very little influence on the training processes. In the second step of the analyses, the distal antecedents were entered to determine their effect on the outcome. The antecedents included the relevant error training elements, individual differences, and interactions. In the third step, the relevant process variables were entered to determine whether they explained further variance in the outcome. If the second and third steps are both significant, then the second and third conditions of mediation are supported and the steps can be reversed to determine whether controlling for the processes reduces the variance explained by the antecedents.

Separate analyses were conducted for the instructional, motivational, and emotional components of the model. The outcomes examined included basic and strategic knowledge as well as basic and strategic near and far transfer performance. The original model specified that the effects on generalization performance would operate through knowledge and near transfer skills. However, the decision was made to treat these variables all as final outcomes for two reasons. First, the effects of the error training elements on knowledge were very modest and, in general, there were more consistent and stronger effects on generalization rather than near transfer performance. Second, the relationships among these three outcomes are basically assumed and are not really of much theoretical interest. Table 4 shows that these outcomes evidenced strong

relationships with one another. More important is whether the process variables mediate the effects of the antecedents on individuals' generalization performance.

Instructional antecedents and processes. The first set of mediation analyses examined the incremental effects of the instructional antecedents and processes on trainees' knowledge and performance. The results of these analyses are summarized in Table 17. It should be noted that intrinsic motivation was included as a motivational process variable rather than an instructional process variable because it was not directly influenced by the instructional element, only the instructional x motivational interaction. The analyses in which the instructional processes were entered in the second step after controlling for ability revealed that hypothesis-testing had a significant and positive effect on trainees' strategic performance during near transfer ($\beta = .192, p < .01$) and strategic performance during far transfer ($\beta = .203, p < .01$). Thus, Hypothesis 4b was partially supported. The results also revealed that metacognitive activity had a marginally significant effect on individuals' strategic performance during near transfer ($\beta = -.123, p < .05$) and basic performance during far transfer ($\beta = .119, p < .10$). Consistent with expectations, higher levels of metacognitive activity led to higher levels of basic performance during far transfer. Contrary to expectations, higher levels of metacognitive activity resulted in lower levels of strategic performance during near transfer. The results also showed that self-evaluation activity was significantly and positively related to trainees' strategic performance during near transfer ($\beta = .157, p < .05$), strategic performance during far transfer ($\beta = .187, p < .01$), and strategic knowledge ($\beta = .154, p < .01$). Finally, cognitive effort displayed a marginally significant relationship with basic performance during far transfer ($\beta = -.093, p < .10$) and a significant relationship with

strategic performance during far transfer ($\beta = -.121, p < .05$). Contrary to expectations, higher levels of cognitive effort were associated with lower levels of performance. Thus, Hypothesis 6b was unsupported.

The results reported above suggest that hypothesis-testing and self-evaluation activity played an important role in the development of trainees' knowledge and, in particular, skills. What is interesting about these results is that both hypothesis-testing and self-evaluation activity evidenced relationships with the strategic but not the basic outcomes. Thus, it appears that these self-regulatory activities are especially critical when the goal is to develop more complex and strategic knowledge and skills. In general, metacognitive activity and cognitive effort did not exhibit strong relationships with the training outcomes. In addition, the significant effects that emerged for these processes were mixed and somewhat inconsistent with expectations. For example, although metacognitive activity was positively related to basic performance during far transfer, there was a negative relationship between metacognitive activity and strategic performance during near transfer. In addition, cognitive effort led to lower levels of performance during far transfer. It is worth noting that cognitive effort early in training did not exhibit these negative effects on knowledge and performance. On the other hand, although not significant, cognitive effort early in training generally displayed positive relationships with trainees' knowledge at the end of training and their performance in the transfer trials. Thus, it may be that a high level of cognitive effort at the end of end of training is indicative of individuals who had considerable trouble learning the training material, the use of poor learning strategies (e.g., repetition), or cognitive overload.

After examining the effects of instructional processes, I then performed hierarchical regression analyses to examine the incremental effects of the instructional antecedents and instructional processes. The results revealed that the instructional processes were not significantly related to basic performance in near transfer and basic knowledge, and the instructional antecedents were not significantly related to basic or strategic knowledge. As a result, mediation could not be tested with these outcomes.

When entered in the second step of the regression equation, the instructional antecedents accounted for marginally significant variance in strategic performance in the near transfer trial ($\Delta R^2 = .055, p < .10$) beyond that accounted for by cognitive ability, while the addition of the instructional processes in the third step resulted in further variance explained ($\Delta R^2 = .048, p < .05$). When the order of the steps was reversed, the variance in near transfer strategic performance explained by the instructional antecedents was not reduced ($\Delta R^2 = .057, p < .05$), which suggests that the instructional processes did not mediate the effect of the instructional antecedents on near transfer strategic performance. A similar result emerged for trainees' basic and strategic performance in far transfer. The instructional antecedents accounted for significant variance in far transfer basic ($\Delta R^2 = .054, p < .10$) and strategic performance ($\Delta R^2 = .052, p < .10$) over and above ability, and the instructional processes accounted for additional variance explained when entered in the third step ($\Delta R^2 = .043, p < .01$; $\Delta R^2 = .089, p < .01$). When the order of the steps was reversed, the variance explained by the instructional antecedents remained significant and was not reduced ($\Delta R^2 = .058, p < .05$; $\Delta R^2 = .069, p < .01$).

On the surface, the results above suggest that the instructional processes did not mediate the effects of the instructional antecedents on trainees' knowledge and performance. However, a closer examination of the results suggests a potential alternative explanation. Specifically, it appears that controlling for the instructional processes reduced the effects of several of the instructional antecedents but enhanced the impact of others. For example, trait learning orientation's significant relationship with individuals' strategic performance in near transfer and basic performance in far transfer was reduced when the instructional processes were controlled. Similar results were found for the interactive effects of the instructional element and learning orientation and the instructional element and avoid orientation on several of the outcomes. At the same time, however, the results revealed that controlling for the instructional processes actually enhanced the main effect of the instructional element on individuals' performance. This most likely occurred because the instructional element had significant effects on a number of processes, some of which had positive effects and others that had negative effects on the outcomes. There tended to be more positive than negative effects, so the result was a moderate, positive relationship between the instructional element and the outcomes. But, when the variance explained by these conflicting effects was controlled a stronger, positive relationship between the instructional element and the outcomes emerged. Overall, the reduction in variance explained by some antecedents and increase in variance explained by the instructional element resulted in little change in overall variance explained by the set of antecedents in different steps of the mediation analyses. Although this does not fit the definition of classic mediation, it does suggest that these

processes explained a portion of the relationship between the instructional antecedents and the outcomes.

Motivational antecedents and processes. Two sets of mediation analyses were performed involving the motivational antecedents and processes. The first set of analyses examined whether state goal orientation mediated the effects of the motivational antecedents on trainees' intrinsic motivation and self-efficacy. State anxiety was included as an emotional rather than a motivational process variable because it was not influenced by the motivational element or its interaction with any of the individual differences.⁸ In addition, analyses revealed that state anxiety displayed a significant relationship with state performance-avoid orientation ($\beta = .188, p < .01$), but was not significantly related to learning orientation or performance-prove orientation. The second set of analyses examined whether self-efficacy and intrinsic motivation mediated the effects of the motivational antecedents, including state goal orientation, on individuals' basic and strategic knowledge and performance.

As expected, the first set of analyses revealed that state goal orientation had a significant effect on trainees' self-efficacy and intrinsic motivation. Self-efficacy was significantly and positively related to state learning orientation ($\beta = .323, p < .01$) and performance-prove orientation ($\beta = .205, p < .01$), and significantly and negatively related to state performance-avoid orientation ($\beta = -.324, p < .01$). Thus, Hypothesis 13a was supported. Intrinsic motivation was also significantly and positively related to state learning orientation ($\beta = .370, p < .01$) and state performance-prove orientation ($\beta = .161, p < .01$), and significantly and negatively related to state performance-avoid orientation ($\beta = -.170, p < .01$). Thus, Hypothesis 12 was supported.

The mediation results for this first set of analyses, presented in Table 18, suggest that state goal orientation also mediated the effects of the motivational antecedents on trainees' self-efficacy and intrinsic motivation. When entered in the second step of the regression equation, the motivational antecedents accounted for significant variance in self-efficacy ($\Delta R^2 = .154, p < .01$) beyond that accounted for by cognitive ability, while the addition of state goal orientation in the third step resulted in further variance explained ($\Delta R^2 = .123, p < .01$). When the order of the steps was reversed, the variance explained by the motivational antecedents remained significant but was reduced ($\Delta R^2 = .047, p < .05$). This suggests that state goal orientation partially mediated the effect of the motivational antecedents on trainees' self-efficacy. The motivational antecedents also explained significant variance in intrinsic motivation ($\Delta R^2 = .062, p < .05$) after controlling for ability, and the addition of state goal orientation resulted in further variance explained ($\Delta R^2 = .164, p < .03$). When the order of the steps was reversed, the variance explained by the motivational antecedents was reduced to nonsignificance ($\Delta R^2 = .028, ns$), which suggests that the effect of the motivational antecedents on individuals' intrinsic motivation was mediated by state goal orientation.

The second set of analyses examined whether self-efficacy and intrinsic motivation mediate the effects of the motivational antecedents, including state goal orientation, on trainees' knowledge and performance. The results showed that self-efficacy was significantly and positively related to individuals' near transfer basic performance ($\beta = .214, p < .01$) and far transfer basic performance ($\beta = .194, p < .01$) and exhibited a marginally significant relationship with far transfer strategic performance ($\beta = .086, p < .10$). Thus, Hypothesis 13b was mostly supported. Intrinsic motivation was

significantly and positively related to near transfer strategic performance ($\beta = .145, p < .01$), far transfer basic performance ($\beta = .147, p < .01$), far transfer strategic performance ($\beta = .123, p < .05$), basic knowledge ($\beta = .138, p < .01$), and strategic knowledge ($\beta = .108, p < .05$). Thus, Hypothesis 7b was mostly supported.

The mediation results for the second set of motivational analyses are presented in Table 19. Mediation could not be tested on several outcomes because the motivational antecedents failed to account for significant variance in these outcomes. However, the motivational antecedents did explain significant variance in basic performance during far transfer ($\Delta R^2 = .078, p < .01$) beyond that accounted for by cognitive ability, while the addition of self-efficacy and intrinsic motivation in the third step resulted in further variance explained ($\Delta R^2 = .050, p < .01$). When the order of the steps was reversed, the variance explained by the motivational antecedents remained significant ($\Delta R^2 = .055, p < .05$), but was reduced. The motivational antecedents also explained significant variance in basic knowledge ($\Delta R^2 = .060, p < .10$) over and above ability, and the motivational processes accounted for a marginally significant ($\Delta R^2 = .015, p < .10$) increase in variance explained when entered in the third step. When the steps were reversed, the variance in basic knowledge explained by the motivational antecedents was reduced to nonsignificance ($\Delta R^2 = .043, ns$).

Overall, the results reviewed above suggest that the motivational processes largely operated as expected. Learning orientation and performance-prove orientation displayed positive relationships with self-efficacy and intrinsic motivation, while performance-avoid orientation exhibited a negative relationship with self-efficacy and intrinsic motivation. Furthermore, the mediation analyses revealed that state goal

orientation mediated the effects of the motivational antecedents on trainees' self-efficacy and intrinsic motivation. Self-efficacy, in turn, showed a positive relationship with several of the performance outcomes and intrinsic motivation had a positive effect on all the knowledge and performance outcomes, except near transfer basic performance. The analyses provided some support for the mediational role of self-efficacy and intrinsic motivation. More specifically, self-efficacy and intrinsic motivation partially mediated the effect of the motivational antecedents on trainees' far transfer basic performance and basic knowledge.

Emotional antecedents and processes. The final set of mediation analyses examined the incremental effects of the emotional antecedents and processes. Hypothesis 19b predicted that feelings of personal control would have a significant effect on state anxiety. Analyses revealed that after controlling for cognitive ability, feelings of control exhibited a marginally significant, negative relationship with state anxiety ($\beta = -.091$, $p < .10$). Thus, some support was found for Hypothesis 19b. The conceptual model, presented in Figure 1, suggested that feelings of control would partially mediate the effect of the emotional element on state anxiety. However, analyses revealed that feelings of control did not mediate the relationship between the emotional antecedents and state anxiety. Thus, both state anxiety and feelings of control were used together as potential mediators of the effects of the emotional antecedents on trainees' knowledge and performance.

The analyses in which the emotional processes were entered in the second step of the regression after controlling for cognitive ability revealed that feelings of control exhibited a significant and positive relationship with trainees' near transfer basic

performance ($\beta = .174, p < .01$) and far transfer basic performance ($\beta = .179, p < .01$), but did not significantly relate to strategic performance or knowledge. The analyses also revealed that state anxiety only exhibited a significant relationship with strategic knowledge ($\beta = .102, p < .05$). Contrary to expectations, individuals with higher levels of state anxiety displayed higher levels of strategic knowledge. Thus, Hypothesis 14b was not supported. It is important to recognize that the average level of anxiety experienced by participants in this study was relatively moderate. Past research has shown that rather low or high levels of physiological arousal produce negative effects on performance, while moderate levels of arousal can enhance performance.⁸ Thus, it may be that trainees in the current study did experience anxiety levels high enough to limit their ability to learn and perform well. Yet, the ability of the emotion-control training to reduce individuals' anxiety is still important. In a situation where anxiety levels are relatively high during training, the emotion-control training may lead to an even greater reduction in anxiety and would, therefore, probably evidence more positive effects on trainees' knowledge and performance.

The results for the mediation analyses that examined the incremental effects of the emotional antecedents and processes are displayed in Table 19. Although the emotional processes influenced several of performance and knowledge outcomes, the combined set of emotional antecedents did not have a significant influence on trainees' knowledge or performance. As a result, it was not possible to test whether the emotional processes mediated the effect of the emotional antecedents.

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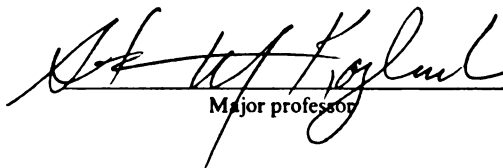
AN EXAMINATION OF THE INSTRUCTIONAL, MOTIVATIONAL,
AND EMOTIONAL ELEMENTS OF ERROR TRAINING

presented by

Bradford S. Bell

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Psychology



Major professor

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**AN EXAMINATION OF THE INSTRUCTIONAL, MOTIVATIONAL, AND
EMOTIONAL ELEMENTS OF ERROR TRAINING**

VOLUME II

By

Bradford S. Bell

A DISSERTATION

**Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of**

DOCTOR OF PHILOSOPHY

Department of Psychology

2002

DISCUSSION

Over the past decade, we have witnessed substantial change in the nature of work and organizations (Salas & Cannon-Bowers, 2000). Advances in technology have made jobs that once required lower level perceptual or motor skills more cognitively complex and demanding (Tannenbaum & Yukl, 1992). Technological advances have also heightened the pace of change making the nature of work more dynamic and ill-structured. Other changes that have occurred in organizations, such as the shift to team-based work structures, the growing focus on quality, and the movement toward reengineering, have transformed the nature of work and have made human resources even more critical to organizational effectiveness (Ford & Fisher, 1997). Finally, the globalization of business and recent downturns in the economy have created pressures for improved efficiency, cost-control, and organizational effectiveness.

As a result of these changes and pressures, organizations must, now more than ever, rely on workplace learning in order to gain competitive advantage (Salas & Cannon-Bowers, 2000). At the same time, however, there has been a growing realization that many of our traditional training tools and principles are not well suited to meet these emerging challenges. Three fundamental assumptions underlie many of our traditional training techniques – (1) work environments are largely predictable and stable; (2) the requisite knowledge and skills of jobs, therefore, can be identified and remain constant across time; and (3) individuals who receive extensive training on these specific knowledge and skills will exhibit higher levels of job performance (Smith et al., 1997). However, the fact is that many modern work environments are largely unpredictable and are in a constant state of change, the knowledge and skills needed to perform many jobs

must be adapted and updated frequently, and routine expertise has been shown to often to be more a liability than an asset in dynamic work environments (Devine & Kozlowski, 1995; Hesketh, 1997; Sternberg & Frensch, 1992).

Due to the limitations associated with a number of our traditional training techniques and principles, considerable attention in recent years has been devoted to developing new instructional approaches that are better suited to meet the emerging training challenges. Active learning is one approach that appears to hold considerable potential. Active learning is a general term that refers to a breed of instructional strategies designed to increase the participation of individuals in their learning and facilitate a more active and inductive learning process (Brown & Ford, 2002; Smith et al., 1997). The goal of active learning is to stimulate mindful, effortful learning and systematically influence a host of instructional, motivational, and emotional processes that are critical to the development of flexible, generalizable skills. Interest in these active learning strategies has grown as research has demonstrated that they often lead to increased learning and performance as well as enhanced transfer of skills (e.g., Frese, 1995; Ivancic & Hesketh, 1995/1996; McDaniel & Schlager, 1990; Nordstrom et al., 1998).

The current study provided a comprehensive examination of error training, which is one of the more popular active learning strategies to emerge in recent years. In contrast to the more traditional approach to training, error training utilizes an unstructured and exploratory learning environment, encourages trainees to make rather than avoid errors, and attempts to control individuals' emotions during training. Research has shown that error training can lead to increased learning and retention and

facilitate the development of generalizable skills (e.g., Frese, 1991; Frese et al., 1991; Nordstrom et al., 1998). However, our understanding of error training has been limited by the fact that past research has (1) confounded the key elements that distinguish error training from more traditional training approaches, and (2) has not examined the various mechanisms by which error training may impact learning and performance. Thus, the primary goal of the current study was to decompose the instructional, motivational, and instructional elements of error training, determine their independent and interactive effects on important training outcomes, and identify the mechanisms or processes by which these elements have their effects.

It is important to recognize that the core elements that define error training can be found in a number of active learning techniques, such as discovery learning (McDaniel & Schlager, 1990; Smith, 1996), guided exploration (Debowski, Wood, & Bandura, 2001), and mastery training (Kozlowski et al., 2001; Stevens & Gist, 1997). Therefore, at a broader level, this study provides insight into the basic components of active learning techniques, such as exploratory learning, a learning oriented training environment, and emotion-control interventions. It also highlights the cognitive, behavioral, and affective mechanisms by which the components exert their effects and enhances our understanding of the role of individual differences in active learning. The knowledge gained should stimulate future research on active learning and prove useful as we develop new learning tools and techniques that make use of active learning principles.

In the following sections I provide a summary of the key findings of the present research. I begin with a general overview of the findings and then discuss specific results surrounding the instructional, motivational, and emotional elements of error training. I

then discuss the limitations and boundary conditions of the current study. Finally, I conclude with the implications of the findings for future research, organizational practice, and training design.

Overview of Findings

Table 1 provides a summary of the results for each hypothesis tested in the current study. In addition, Figures 23 through 25 are heuristics that summarize the findings for the instructional, motivational, and emotional elements and mechanisms. If a direct effect was found, the direction of the effect is indicated. Also, individual differences that moderated relationships between the error training elements and mechanisms are specified on the relevant paths. Direct effects for the individual differences are not depicted to simply presentation of the results. The specific results summarized in these figures will be discussed in greater detail below. However, before discussing the results for the individual elements, it is useful to first discuss the overall results for the major issues addressed in this research.

Influence of elements on training outcomes. One issue the current study was designed to address is the relative impact of the three error training elements on individuals' knowledge and performance. Past research has typically combined the error training elements into a single intervention, which has prevented a comparison of their relative influence. As a result, it has been difficult to determine which element(s) of error training account for past findings. The results of the current study showed that the instructional and motivational elements influenced trainees' knowledge and performance. These elements primarily impacted individuals' far transfer or generalization performance, which is consistent with the theoretical underpinnings of active learning

(McDaniel & Schlager, 1990; Smith et al., 1997). The emotional element, however, did not display a significant influence on knowledge and performance, although it did influence several of the training processes, which, in turn, exhibited relationships with trainees' knowledge and performance.

These results suggest that the instructional and motivational elements may be the most critical components of error training. Indeed, these elements displayed the most pervasive effects on the training processes and outcomes examined in the current study. The emotional element, however, did not exhibit the same positive effects and in fact had a negative influence on several of the outcome variables. Yet, the impact of the emotion-control training on individuals' affective reactions suggests that the emotional element may play an important role in error training, particularly under certain circumstances. These issues will be discussed in more detail below.

Mechanisms of error training. A second goal of the current study was to provide an examination of the paths by which error training has its effects. With a few exceptions (e.g., Dormann & Frese, 1994; Nordstrom et al., 1998), past research on error training has been limited in its focus on potential process variables. Yet, theoretical work has suggested numerous instructional, motivational, and emotional variables by which error training may impact learning and performance (Frese, 1995; Ivancic & Hesketh, 1995/1996). Frese (2002) and others have suggested that the benefits of error training result from these processes, not the act of making errors. The present research, therefore, examined the effects of the error training elements on a number of cognitive, behavioral, and affective training processes. The results revealed that the instructional and emotional elements both influenced several of the training processes. The instructional element led

to increased metacognitive activity, self-evaluation activity, and cognitive effort, while the emotional element led to higher levels of self-efficacy and decreased state anxiety. The effects of the motivational element were not as straightforward and were influenced largely by the nature of the instructional environment and several individual difference characteristics.

Two additional findings surrounding the process variables are worth noting. First, exploratory analyses showed that the error training elements generally only influenced those process variables within their domain. In other words, the instructional manipulation did not evidence an effect on the motivational processes or emotional processes, the motivational manipulation did not evidence an effect on the instructional or emotional processes, and so forth. This provides support for the presence of three distinct elements in error training that operate through separate mechanisms. Second, the training processes exhibited substantial relationships with many of the training outcomes. These results provide additional support for the need to examine the mechanisms by which error training has its effects. Furthermore, the results revealed that the effects of several processes were dependent on the nature of the outcome being examined. For example, the instructional processes, such as hypothesis-testing and self-evaluation activity, largely influenced the generalization and more strategic outcomes, while a number of the motivational and emotional processes, such as self-efficacy and feelings of control, had their primary influence on the basic outcomes. These results implicate different types of processes in the development of different types of knowledge and skills, which suggests that it may be important to target different learning processes depending on the goals of the training program

Role of individual differences in error training. A final issue examined in the current study involved the role of several individual differences in error training. Although considerable research has examined the role of individual differences in instructional programs (for a review see Snow, 1986), research on error training, and active learning more generally, has not focused much attention on determining the influence of individual differences (for an exception see Gully et al., 2002). The results of the current study revealed that a number of individual differences moderated the effects of the error training elements. Cognitive ability and trait goal orientation had the most consistent effects, although openness to experience, conscientiousness, and trait anxiety also appear to have some influence on the effects of specific error training components. It is also important to point out that all the individual differences exhibited substantial, direct relationships with the training processes. These results are important because there is interest in not only determining how to stimulate active learning through training design but also identifying the characteristics of self-directed, active learners (Anderman & Young, 1994; Fisher & Ford, 1997).

Instructional Element

In the current study, the instructional element involved the type of learning strategy or approach used by participants to learn the task. Whereas traditionally training has used proceduralized instruction to guide individuals step-by-step through the training process, error training provides trainees with an unstructured and exploratory learning environment. A number of researchers have suggested that the exploratory nature of error training is critical to its success (Dormann & Frese, 1994; Greif & Janikowski, 1991; Hiltcher & Frese, 1994). Such an assertion is reasonable given that considerable

research has demonstrated that exploratory learning induces an active, mindful approach to learning, which in turn often leads to increased learning, performance, and generalization (e.g., Frese et al., 1988; Kamouri et al., 1986; McDaniel & Schlager, 1990). Yet, the impact of the exploratory component of error training has never been directly examined. Thus, in an attempt to determine the relative importance of exploratory learning in error training, individuals in the current study received either proceduralized instruction or exploratory learning.

Knowledge and performance. It was hypothesized that individuals who received exploratory learning and proceduralized instruction would exhibit similar levels of performance during near transfer, but exploratory instruction would stimulate higher levels of performance during far transfer. As would be expected, individuals who received exploratory instruction displayed lower levels of performance during training. This is consistent with the fact that proceduralized instruction is designed to guide individuals through training. Also consistent with expectations, exploratory learning and proceduralized instruction led to similar levels of performance on the near transfer trial, but exploratory learning led to significantly higher levels of performance on the far transfer trial. These results, which are shown in Figure 2, are consistent with the cross-over effect suggested by a number of researchers (McDaniel & Schlager, 1990; Salomon & Perkins, 1989; Schmidt & Bjork, 1992). That is, more active, mindful learning, although not necessarily producing better outcomes during training or near transfer, leads to farther transfer than more passive, proceduralized instruction. Such findings also demonstrate that when the goal of training is to facilitate far transfer, assessment of

trainees' skills during or immediately following instruction may not provide an accurate indication of training effectiveness.

Past research has speculated that the effectiveness of exploratory learning may depend on nature of the skills being trained. Although dissenting opinions exist, it has been argued that exploratory learning may be best suited for developing more complex skills (Clark & Voogel, 1985; Heimbeck et al., 2000). Therefore, in the current study, the impact of exploratory learning was examined for both basic and complex skills. The results showed that exploratory learning had similar effects on trainees' basic and strategic far transfer performance. Together, these results suggest that the benefits of the instructional element are linked to the extent to which individuals must generalize their skills, not the complexity of those skills.

It was also expected that exploratory learning would lead to higher levels of knowledge than proceduralized instruction. Although the instructional element did not have a significant, direct effect on knowledge, it did interact with the motivational element to influence trainees' basic knowledge. Trainees who received exploratory learning and error encouragement exhibited the highest level of knowledge, and trainees given proceduralized instruction and error avoidance displayed the lowest levels of knowledge. The other two groups, who received a mix of error training and non error-training elements, displayed moderate levels of knowledge. Thus, it appears that there is some gain in knowledge associated with both exploratory learning and error encouragement, but the greatest gain is achieved when these elements are paired together.

It is important to recognize that overall the effect of the error training elements on individuals' knowledge was relatively modest. One potential explanation for this finding

concerns how knowledge was measured in the current study. The knowledge tests used in this study essentially measured the quantity of individuals' knowledge. However, numerous researchers have suggested that error training and other active learning techniques may impact the quality of individuals' knowledge in the form of more complete and accurate mental models (Frese et al., 1988; Frese & Zapf, 1994; Kozlowski et al., 2001; Rasmussen, 1990). While there is certainly some overlap in these constructs, the quantity and quality of knowledge are distinct. Future research, therefore, may benefit by employing techniques such as Pathfinder analysis or multi-dimensional scaling (MDS) that would enable an examination of how error training impacts the nature (e.g., coherence) of trainees' of mental models.

It was hypothesized that the instructional and emotional elements would interact to influence the training outcomes. Specifically, I predicted that the emotion-control training would be more critical when individuals received exploratory as compared to proceduralized instruction. The results did not support this hypothesis. This is most likely due to the fact that higher levels of state anxiety did not lead to decrements in knowledge or performance in the current study. Thus, although the emotion-control training reduced trainees' anxiety, the benefits associated with this reduction were minimal.

Instructional mechanisms. It has been suggested that the effects of error training on trainees' knowledge and performance may be partially explained by a number of cognitive processes, such as metacognitive activity, hypothesis-testing, and effortful, controlled processing (Ivancic, 1998; Ivancic & Hesketh, 1995/1996; Irmer et al., 1991; Frese et al., 1991). Furthermore, it has been argued that the impact of error training on

trainees' cognition emerges largely from the exploratory nature of the instructional environment employed during training. Thus, in the present research I examined the effects of the instructional element on a number of instructional, or cognitive, mechanisms.

It has been suggested that exploratory learning stimulates individuals' metacognitive and self-regulatory processes. Thus, in the current study, the effect of exploratory learning on trainees' metacognitive and self-evaluation activity was examined. Consistent with expectations, exploratory learning had a significant, positive effect on trainees' metacognitive activity. In addition, exploratory learning interacted with the motivational element to influence trainees' self-evaluation activity. Trainees given exploratory learning and error encouragement and those given proceduralized instruction and error avoidance displayed higher levels of self-evaluation activity than the groups that received mixed training elements. Trainees who received inconsistent training elements, such as proceduralized instruction and error encouragement, probably had more difficulty identifying appropriate goals and standards that they could use to evaluate their progress. As a result, these individuals may have experienced difficulty determining what criteria they should be using to evaluate their progress.

These results are important because analyses revealed that both metacognition and self-evaluation activity were related to a number of the training outcomes. Interestingly, self-evaluation activity had a positive relationship with only trainees' strategic knowledge and performance, which suggests that the self-evaluation of progress may be particularly critical for developing more complex skills. Metacognition exhibited somewhat mixed effects. While metacognitive activity was positively related to individuals' basic

performance in far transfer it was negatively related to their strategic performance in near transfer. There are two potential explanations for these findings. First, the basic performance components are the most salient aspect of the task used in the current study. Therefore, it may be that individuals who engaged in high levels of metacognitive activity regulated around these basic task components, which increased their basic performance but detracted from their strategic performance. Second, it may be that metacognitive activities are particularly important for developing generalizable (far transfer) skills. This would be consistent with Smith and colleagues' (1997) argument that the effects of active learning on adaptive expertise are partially the result of increased metacognition.

The effects of exploratory learning on individuals' cognitive effort and hypothesis-testing activity were also examined. The results revealed that, as expected, exploratory learning led to increased cognitive effort both early and later in training. In addition, early in training this effect was moderated by the motivational element, such that exploratory learning only led to increased cognitive effort when paired with error encouragement directions. Unexpectedly, cognitive effort later in training exhibited a negative relationship with trainees' near transfer basic performance and far transfer strategic performance. However, cognitive effort in the early and intermediate stages of training did not exhibit these same negative effects and, in fact, tended to relate positively to trainees' knowledge and transfer performance. These results contradict the argument that extending the length of more effortful, controlled learning will enhance performance (Frese, 1995; Ivancic & Hesketh, 1995/1996). Research has shown that an important stage of learning is the proceduralization of skills, which leads to less effortful, automatic

processing of information (Anderson, 1983). Therefore, trainees who do not make this transition and continue to display high levels of cognitive effort at the end of training may display lower levels of knowledge and performance. The results revealed that the instructional element did not directly influence trainees' hypothesis-testing activities; however, as I will discuss below, the nature of instruction interacted with trait learning orientation to influence hypothesis-testing.

Analyses were conducted to examine whether the cognitive processes mediated the effect of the instructional element on trainees' knowledge and performance. The results revealed that controlling for the cognitive processes reduced the impact of a number of instructional antecedents, but actually enhanced the positive effect of exploratory learning. This is most likely due to the fact that exploratory learning influenced a number of the cognitive processes, some of which had a positive relationship with the outcomes and others that had a negative relationship. While not consistent with classic mediation, these results suggest that the instructional element does operate through these cognitive processes. More importantly, however, these results suggest that the benefits of exploratory learning may be enhanced by eliminating some of its drawbacks, such as increased cognitive effort later in training. Some research has been conducted in this area and suggests that exploratory learning may be more effective when trainees are given adequate guidance (e.g., Bell & Kozlowski, in press), task feedback is clear and specific (Debowski et al., 2001), and trainees' possess prior knowledge of the content area. Yet, other important factors are likely to exist and additional research is needed.

Instructional impact of individual differences. This study included a number of individual differences that were expected to moderate the effects of the error training elements. Before discussing the interactions that emerged in the results, it is important to first note the influence that several of these individual differences had on the instructional mechanisms.

Consistent with previous research (e.g., Fisher & Ford, 1997; Ford et al., 1998), trait goal orientation had a significant influence on the cognitive processes. Individuals with higher levels of learning orientation exhibited more hypothesis-testing and metacognitive activity. Also, individuals with higher levels of performance-prove orientation displayed higher levels of cognitive effort, which is consistent with their desire to do well and demonstrate their competence.

The results also showed that openness influenced a number of the cognitive processes. Openness was positively related to trainees' hypothesis-testing and metacognitive activity and cognitive effort. Although past research has shown that openness is positively related to training proficiency (Barrick & Mount, 1991), the processes underlying this relationship are not as well known. The results of the current study suggest that the benefits of high levels of openness may be linked to heightened levels of cognitive activity.

Finally, conscientiousness was shown to relate positively to both hypothesis-testing and metacognitive activity. These results may be tied to the achievement striving dimension of conscientiousness. Individuals high in achievement striving have a desire to excel and tend to be more self-centered (Moon, 2001), which may make these

individuals more interested in evaluating their progress and testing the boundaries of their knowledge and skills.

In addition to examining the direct effects of the individual differences, I also explored whether the individual difference characteristics moderated the effects of the instructional element. Past research has suggested that more unstructured, error-filled training may be best suited for individuals with higher levels of ability (Gully et al., 2002; Ivancic & Hesketh, 1995/1996). It is thought that the higher levels of cognitive effort required in exploratory learning may overload low ability individuals and high ability individuals may be better equipped to make effective use of the increased learner control.

The results revealed that cognitive ability moderated the effect of the instructional element on trainees' strategic knowledge and performance as well as their metacognitive activity. Although individuals high in ability reported lower levels of metacognitive activity when given proceduralized instruction, they had similar and high levels of strategic knowledge and performance in the two instructional conditions. Contrary to expectations, individuals low in ability displayed higher levels of strategic knowledge and performance when given exploratory instruction. This unexpected finding may be explained by the nature of the task used in the current study. Past research on exploratory instruction has used relatively proceduralized tasks (e.g., word processing). Performance on such tasks can be broken down into a simple set of steps and commands that are easily learned. In the current study, however, individuals needed to learn both basic and strategic skills. Whereas the instructions for the basic task components were relatively straightforward, the instructions for the strategic task elements were more complex. They

required trainees to perform a more elaborate set of task operations and these operations needed to be sequenced and timed properly. The findings above suggest that while high ability individuals were able to extract the strategies from these instructions, low ability trainees were not. In fact, the results suggest that the complexity of these instructions may have confused or overloaded low ability trainees and inhibited their ability to learn the strategic material. Thus, when dealing with more complex and strategic skills, proceduralized instruction may only be practical when the relevant learning activities can be presented in a simplified and straightforward fashion or trainees have higher levels of cognitive ability.

It was also expected that the effects of the instructional element would be moderated by individuals' openness to experience. Only minimal support was found for this hypothesis. Individuals high in openness displayed greater performance efficiency when given exploratory as compared to proceduralized instruction, but the type of instruction did not influence the performance of individuals low in openness. This result is consistent with Gully et al.'s (2002) assertion that error training may benefit individuals high in openness because they are more likely to engage in exploratory behaviors.

Although not formally hypothesized, some evidence was also found for the moderating role of trait goal orientation on the effects of the instructional element. Trait learning orientation moderated the effect of the instructional element on individuals' strategic knowledge and performance as well as several of the cognitive processes. Individuals high in learning orientation displayed similar levels of knowledge, performance, and cognitive activity in both instructional conditions, but individuals low

in learning orientation displayed more positive outcomes when given exploratory instruction. Individuals high in learning orientation are naturally active learners (Fisher & Ford, 1997; Ford et al., 1998). However, individuals low in learning orientation have been shown to exhibit less active learning patterns. It follows then that exploratory learning should produce the greatest gains for individuals low in learning orientation.

The results also revealed that trait performance-avoid orientation moderated the effect of the instructional element on several outcomes. In general, exploratory learning was only effective for individuals low in avoid orientation. This finding is consistent with recent research that has shown that training interventions designed to increase active learning are more effective for individuals low rather than high in avoid orientation (Schmidt & Ford, 2002). Individuals high in avoid orientation strive to avoid a demonstration of normative incompetence and, therefore, are probably less willing to engage in activities, such as exploration or self-evaluation, that may increase or highlight errors.

Finally, exploratory analyses examined conscientiousness as a potential moderator of the effects of the instructional element. The results revealed that conscientiousness interacted with the instructional element to influence trainees' basic performance in near transfer. This interaction was such that individuals high in conscientiousness performed better when given exploratory rather than proceduralized instruction. Individuals high in conscientiousness tend to more self-directed and self-centered. Thus, it may be that the proceduralized instruction was too restrictive for individuals who were high in conscientiousness and wanted to structure their own learning activities. However, one would also suspect that other dimensions of

conscientiousness, such as dependability, would serve as a limitation in situations characterized by lower levels of performance and more errors. Thus, future research is clearly needed before we reach conclusions about the role of conscientiousness in error training.

Motivational Element

The motivational element refers to the type of error instructions individuals' were given during training. In traditional training programs, errors are framed as negative events that should be avoided because they will inhibit learning and performance. In error training, however, individuals are encouraged to make errors. Essentially, error training attempts to reframe errors as serving a positive function in the learning process. Whereas the exploratory nature of error training has been used to induce errors and engage individuals' cognitive processes, the error instructions have been used primarily to influence trainees' motivational processes (Frese, 1995; Ivancic & Hesketh, 1995/1996). It has been suggested that reframing errors as positive learning experiences should reduce the negative motivational consequences typically associated with errors. In addition, individuals may be more likely to adopt a learning orientation, find the training more intrinsically motivating, and experience higher levels of self-efficacy. To test these hypotheses, trainees in the current study received either error encouragement or error avoidance directions. The effects of these directions on knowledge and performance as well as several motivational mechanisms are reviewed below.

Knowledge and performance. Past research on error training has suggested that the positive effects of error training on knowledge and performance are due, in part, to the positive motivational implications of error encouragement directions. The results of

the current study provide support for this argument. Although the motivational element did not influence trainees' overall near transfer performance, error encouragement led to higher levels of far transfer performance than error avoidance. Once again, these results are consistent with the contention that active learning is most appropriate when the goal is to develop generalizable skills and facilitate far transfer. It was also found that error encouragement increased trainees' strategic performance in both the near and far transfer trials and their basic performance in the far transfer trial. When errors are framed positively, trainees may be more willing to attempt the more complex aspects of the training material. These results are important because past research on error training has focused primarily on more basic, proceduralized tasks and the appropriateness of error training for developing more complex skills was largely unknown. It appears from these results that error encouragement may be a useful tool for developing more strategic skills.

It was hypothesized that error encouragement would also lead to higher levels of knowledge than error avoidance. Although the motivational element did not directly influence trainees' knowledge, it did interact with the instructional element to influence trainees' basic knowledge. Error encouragement led to increased knowledge only when paired with exploratory learning. When paired with proceduralized instruction, error encouragement led to similar levels of knowledge as error avoidance directions. The proceduralized instructions probably created the perception that errors were to be avoided, thereby neutralizing the positive effects of error encouragement on individuals' knowledge.

It was proposed that the motivational and emotional elements would also interact to influence trainees' knowledge and performance. More specifically, it was argued that

the emotion-control training should be more important when individuals are told to avoid rather than make errors. Support was not found for this hypothesis. Again, this result is probably tied to the fact that state anxiety did not relate to trainees' knowledge or performance.

Motivational mechanisms. Previous research on error training has suggested that the nature of the error instructions may influence a number of motivational processes, including intrinsic motivation and self-efficacy. In the current study, it was hypothesized that these effects could be explained by the impact of the error instructions on trainees' state goal orientation. Specifically, it was argued that error encouragement would stimulate a state learning orientation and error avoidance would stimulate a state performance-avoid orientation. The results showed that the motivational element did not have a significant direct effect on trainees' state goal orientation. As I will discuss in the next section, this may be due to the fact that the effects of the motivational element on state goal orientation were dependent on trainees' trait goal orientation.

Although the motivational element did not influence trainees' self-efficacy or state anxiety, it interacted with the instructional element to affect trainees' intrinsic motivation. As expected, trainees who received proceduralized instruction and error avoidance directions displayed the lowest level of intrinsic motivation. However, the other three groups did not display significant differences in intrinsic motivation. It appears that as long as trainees are given some control and autonomy, either in the form of exploratory learning or error encouragement, intrinsic motivation is not reduced.

The effects of motivational mechanisms largely followed expectations. It was hypothesized that trainees' state goal orientation would related to intrinsic motivation,

self-efficacy, and state anxiety. The results revealed that state learning and performance-prove orientations were positively related to trainees' self-efficacy and intrinsic motivation, while state performance-avoid orientation was positively related to state anxiety and negatively related to self-efficacy and intrinsic motivation. These results provide further support for the positive effects of learning orientation and the negative effects of performance-avoid orientation (e.g., Chen, Gully Whiteman, & Kilcullen, 2000; Phillips & Gully, 1997; VandeWalle et al., 2001). They are also important because past research has not yet yielded clear evidence of the types of effects associated with performance-prove orientation (e.g., VandeWalle et al., 2001). It appears, at least in the current study, that performance-prove orientation is positively related to a number of training processes and outcomes, including self-efficacy and intrinsic motivation. The results also revealed that self-efficacy and intrinsic motivation tended to display positive relationships with trainees' knowledge and performance. Overall, these results provide additional support for the importance of these motivational processes in training.

Motivational impact of individual differences. Some recent research suggests that several individual difference characteristics may influence the relative effectiveness of error encouragement and error avoidance directions. Gully et al. (2002), for example, found that both conscientiousness and openness to experience moderated the effects of error encouragement. Specifically, they found that error encouragement was more effective for individuals high in openness and low in conscientiousness. Thus, in the current study it was hypothesized that the motivational element would interact with both conscientiousness and openness to influence trainees' knowledge and performance. These hypotheses were not supported. However, as noted earlier, there was some

evidence that both openness and conscientiousness moderate the effects of the instructional element. Thus, it may be that the nature of the instructional environment, not the nature of the error instructions, invokes different responses from individuals with varying levels of conscientiousness and openness. It is difficult to evaluate this hypothesis against the Gully et al. study because individuals in their study encouraged to make errors were also instructed to use learning strategies, such as not using their training manual, that would lead to increased exploration and errors. Future research, therefore, is needed to better determine how the different elements of error training interact with conscientiousness and openness.

Additional analyses revealed that the motivational element interacted with trait learning and performance-avoid orientation to influence trainees' state goal orientation and several other training processes and outcomes. These interactions were very similar to those uncovered among the instructional element and trainees' learning and avoid orientations. Essentially, error encouragement produced positive effects for individuals low in learning and avoid orientations, whereas individuals high in learning and avoid orientations were generally unaffected by the nature of the error instructions. For example, error encouragement increased state learning orientation among individuals low in trait learning orientation and led to lower levels of state avoid orientation for individuals low in trait avoid orientation. Thus, it appears that the error instructions had the desired effects on trainees' state goal orientation, but only among trainees with particular levels of trait goal orientation. These results provide further evidence that incorporating active learning elements into training may help to overcome some of the

limitations associated with low levels of learning orientation and may be more appropriate when trainees' have lower levels of trait performance-avoid orientation.

Given the effects of the motivational element and individual differences on the motivational processes and training outcomes, mediation analyses were conducted to test the motivational paths specified in Figure 1. The results of these analyses showed that state goal orientation partially mediated the effects of the motivational antecedents on trainees' self-efficacy and intrinsic motivation. In addition, intrinsic motivation and self-efficacy partially mediated the effects of the motivational antecedents on trainees' basic performance in far transfer and basic knowledge. These results show that the effects of the motivational antecedents can be explained largely by the effects they have on the motivational mechanisms. These findings highlight the importance of understanding how both training design elements and individual differences influence individuals' motivation during training.

Emotional Element

One of the limitations associated with error training is that errors tend to produce negative affective reactions, such as increased state anxiety, lower feelings of control, and more negative affect and frustration (Frese et al., 1991; Heimbeck et al., 2001). Considerable research has argued that these negative emotions are detrimental to learning and performance because they divert attentional resources away from on-task activities (e.g., DuCette & Wolk, 1973; Kanfer et al., 1994; Mikulincer, 1989; Wood et al., 2000). As a result, past research on error training has typically used emotion-control statements to reduce individuals' anxiety and frustration surrounding errors and poor performance. Although Frese and colleagues have argued that these statements may serve as a

necessary and critical component of error training, past research has failed to provide convincing evidence regarding the importance of the emotion-control statements and the mechanisms through which they have their effects.

In the current study, trainees were randomly assigned to either an emotion-control or no emotion-control condition, which allows for a direct examination of the effects of the emotional element of error training. Trainees in the emotion-control condition received training at the beginning of the experiment designed to help them monitor and suppress any negative emotions that may arise during instruction. In addition, five emotion-control statements were presented on a whiteboard in the training room and periodically on the computer monitor following feedback. I assessed the effect of this emotion-control training on individuals' knowledge and performance as well as a number of emotional processes. The results for the emotional element are reviewed below.

Knowledge and performance. It was argued that trainees' who received emotion-control training would display higher levels of knowledge and performance than trainees who were not given the emotion-control training. This hypothesis was based on the cognitive resource perspective (Kanfer & Ackerman, 1990; Kanfer & Heggestad, 1997; Kanfer et al., 1994). Specifically, by decreasing trainees' negative emotions, the emotion-control training should increase the resources that individuals have available for on-task activities and, subsequently, increase knowledge and performance. The results revealed, however, that the emotion-control training generally did not have a significant impact on trainees' knowledge and performance. In addition, the few significant findings that did emerge were contrary to expectations and showed a negative relationship between the emotion-control and knowledge and performance.

One potential explanation for this finding is that the emotion-control training may have actually led to higher levels of cognitive load or distracted individuals from the task. If this were the case, the negative effects of the emotion-control training should be most pronounced early in training when cognitive resource demands are highest. Some evidence of this was found. This creates a difficult dilemma because it suggests that emotion-control training may impede learning early in training, and yet this is when trainees are most likely to experience negative emotions and emotion-control may be most instrumental.

There is little question that having individuals monitor and control their emotions increases cognitive load and has the potential to detract from individuals' on-task focus. However, it is typically assumed that such effects will be offset by the attentional resources that are freed by lowering trainees' negative emotions. To better understand these findings, therefore, it is critical to examine how the emotion-control training influenced trainees' emotions and the influence these emotions had on knowledge and performance. These issues are addressed next.

Emotional mechanisms. Previous research that has attempted to directly identify the role of the emotion-control statements in error training has failed to measure trainees' affect (e.g., Heimbeck et al., 2001). As a result, it is difficult to determine whether the statements have a meaningful influence on trainees' emotions. In the current study, I examined the influence of the emotion-control training on trainees' state anxiety and feelings of control. I included feelings of control in these analyses because past research suggests that individuals' attributions serve an important mediating role between a stimulus (e.g., failure) and an emotional response (McGrath, 1970). Individuals who

have greater feelings of personal control are more likely to believe they can meet situational demands and are, therefore, less likely to experience anxiety (DuCette & Wolk, 1973).

In the current study, the emotion-control training lowered trainees' state anxiety, as expected. Furthermore, the results revealed that this effect was most pronounced early in training, which is consistent with the belief that emotion-control may be most crucial during early stages of learning due to the greater potential of errors and low performance. The emotion-control training did not have a significant direct effect on trainees' feelings of control, although, as I will discuss below, the emotion-control training interacted with trainees' trait anxiety to influence individuals' attributions. Finally, additional analyses revealed that the emotion-control training had a significant, positive effect on trainees' self-efficacy early in training. This finding is consistent with the nature of the emotion-control training, which encouraged trainees to maintain a positive attitude and self-confidence throughout training.

These findings are somewhat inconsistent with the effects the emotion-control training had on knowledge and performance. Given the significant reduction in trainees' anxiety, one would expect the emotion-control training to lead to gains in knowledge and performance. An examination of the effects of the emotional processes helps to clarify this inconsistency. State anxiety did not display a significant relationship with most of the knowledge and performance outcomes. The only significant finding for state anxiety was a positive relationship with trainees' strategic knowledge. It should be mentioned that trainees' feelings of control exhibited a negative relationship with state anxiety, as expected. Furthermore, trainees who reported greater feelings of control tended to

exhibit higher levels of knowledge and performance. Yet, the modest effects for the emotional antecedents and processes prevented a test of mediation.

These results for the emotional processes help to explain why the emotion-control training did not increase individuals' knowledge and performance. Although the emotion-control training led to lower levels of state anxiety, the effects of state anxiety on trainees' knowledge and performance were negligible. This may have been caused by the fact that trainees in the current study, on average, reported moderate levels of state anxiety. The Yerkes-Dobson law states that low and high levels of physiological arousal will have a negative effect on performance, while moderate levels of physiological arousal may actually enhance performance. Thus, emotion-control training may only be advantageous in situations where there is the potential for trainees to experience high levels of anxiety. When average anxiety levels are more moderate, emotion-control training may serve as more of a distraction than a useful training tool. Thus, it may be important to carefully consider the nature of the situation before deciding whether or not to incorporate emotion-control elements into training.

Emotional impact of individual differences. There is reason to expect that the effects of emotion-control training may depend on several individual difference characteristics. Kanfer and Ackerman (1990), for example, found that their emotion-control intervention benefited low ability trainees, but had little effect for high ability trainees. They argued that low ability trainees benefited the most from the intervention because they were more likely to make errors, experience lower levels of performance, and, therefore, experience higher levels of negative affect. The effects of emotion-control training may also depend on trainees' trait anxiety. Individuals high in trait

anxiety may benefit the most from emotion-control because they are more predisposed to experience state anxiety.

As would be expected, there was a strong, positive relationship between trait and state anxiety. In addition, feelings of control exhibited a positive relationship with learning orientation and a negative relationship with trait anxiety. These results support the importance of dispositional anxiety in determining individuals' situational or state anxiety. There was also a significant interaction between the emotion-control training and cognitive ability on trainees' strategic knowledge. As noted earlier, the emotion-control training led to lower levels of strategic knowledge. However, it was found that this was the case only for individuals low in cognitive ability. This provides further evidence that the negative effects of the emotion-control training on knowledge and performance may have been caused by increased attentional demands.

It was also found that the emotion-control training interacted with both cognitive ability and trait anxiety to influence trainees' feelings of control. The emotion-control training led to increased feelings of control among low ability trainees, but decreased feelings of control among high ability trainees. This finding is consistent with Kanfer and Ackerman's (1990) argument that emotion-control training may have the greatest influence on the affect of trainees with low levels of ability. The results revealed that trait anxiety was negatively related to feelings of control only among trainees who did not receive the emotion-control training. In addition, the emotion-control training increased feelings of control only among individuals high in trait anxiety. This provides some evidence that emotion-control training may be more important for individuals high in trait anxiety.

Overall, the results for the emotional element were mixed. Unexpectedly, the emotion-control training did not have a significant effect on trainees' knowledge and performance. Yet, the emotion-control training did reduce trainees' state anxiety and increased feelings of control among trainees low in ability and high in trait anxiety. I believe these inconsistent findings are due to the fact that trainees' state anxiety did not evidence much of an effect on knowledge and performance. Had trainees experienced higher levels of state anxiety, the overall benefits associated with the emotion-control training would likely have been greater.

Limitations and Directions for Future Research

A few limitations of the current study should be discussed. One limitation involves the potential generalizability of the results. Although there is growing interest in understanding how to conduct training through computer technologies (e.g., Brown, 2001; Debowski et al., 2001), the use of a student sample and synthetic task somewhat limits the extent to which the results of the present study can be directly generalized to other training settings. On the other hand, the instructional paradigm utilized in the current study allowed for a detailed and rigorous examination of many issues that have not yet been addressed in research on error training, including the relative impact of the different error training elements, the role of numerous mechanisms and individual difference characteristics in error training, and the potential utility of error training for developing more complex and strategic skills. However, additional research is clearly needed to extend the current results to other trainee populations, training tasks, and learning environments.

A second issue involves the observed effects for the emotion-control training. Contrary to expectations and prior research, the emotion-control training exhibited negative rather than positive relationships with knowledge and performance. I have suggested that one explanation for these results may stem from the fact that state anxiety did not relate to knowledge or performance in the current study. This may be due to the relatively moderate levels of state anxiety reported by trainees. In situations where anxiety levels are not high enough to cause significant decrements in performance, emotion-control training may be ineffective and in fact may be detrimental due to decreased attentional resources and on-task focus. Future research needs to be conducted to better identify those situations in which it is critical to incorporate an emotion-control intervention into training. Different methods of approaching and implementing emotion-control training should also be examined. For example, it may be useful to gradually phase-out emotion-control interventions over the course of training or possibly implement emotion-control only after trainees have acquired a foundation of knowledge and skills. Finally, future research should explore the impact of emotion-control training on affective reactions besides anxiety, such as negative affect and dissatisfaction.

A related issue that I believe is worth examining is the effects of public and private feedback during error training. Some of the past research on error training has had participants work in pairs during training (e.g., Frese et al., 1991). In contrast to the current study where individuals' performance and feedback were relatively private and not known by others, having individuals train in pairs or groups greatly increases the public nature of feedback. One could argue that when feedback is of a public nature, errors and poor performance may be more anxiety provoking and emotion-control

training and error encouragement may have a larger impact on relevant training processes and outcomes. This may be particularly true in organizational settings where trainees often know one another and may, therefore, be more concerned with impression management. These issues may serve as fruitful avenues of future inquiry.

One goal of the current study was to determine the mechanisms by which error training has its effects. The process-based model presented in Figure 1 was only partially supported. This may stem, in part, from the complexity of the processes underlying error training. Another issue, however, involves the manner in which a number of the mechanisms were measured in the current study. While an attempt was made to use information collected from the task and its associated programs (e.g., on-line manual) to measure several of the training processes, many of the mechanisms were assessed using self-report measures. One issue that arises is whether or not self-report leads to an accurate assessment of particular constructs. It may be difficult, for example, for individuals to recall and report certain cognitive activities, and other constructs, such as intrinsic motivation and state anxiety, may be difficult to accurately capture through a questionnaire. In addition, self-report measures are subject to potential confounds, such as performance attributions. While the current study certainly contributes to our understanding of the mechanisms involved in error training, future research should attempt to examine these and other mechanisms using a variety of techniques. For example, cognitive mapping techniques may provide useful insight into the instructional component of error training, time spent engaged in voluntary practice can serve as an indicator of intrinsic motivation, and anxiety may be best assessed through physiological indicators.

In this study, the individual differences evidenced substantial effects on a number of the training processes and outcomes. However, in several cases, the direct and interactive effects of the error training elements were more modest. This may be explained, in part, by the aptitude-treatment interactions. In other words, the error training elements often had differential effects depending on characteristics of trainees. In such cases, the average or overall effect for the entire sample is reduced. Another factor relates to the effects of decomposing an overall training strategy. When a training approach or intervention is separated into its basic elements, one can expect that the impact of each individual element will be significantly less than that for the full intervention. Thus, it is important to consider the overall effect that might be gained when the elements are utilized in concert. It is also important to realize that even small effects can be substantively meaningful. This is particularly true when we are able to influence or manipulate the effect, as is the case when dealing with the design of training.

Nonetheless, future research should focus on identifying the factors that influence the relative effectiveness of error training and other active learning techniques in order to maximize their impact on trainees' knowledge and performance. The results of the current study suggest that the utility of active learning may depend on not only the desired goals of the training program (e.g., near vs. far transfer) but also the cognitive ability and dispositional traits of trainees. It is critical, therefore, that future research continue to map the boundary conditions of error training and similar training techniques. A better understanding of such conditions should enhance our ability to tap the potential inherent in active learning.

Implications for Practice

As new technological advances emerge and organizations face increasing pressures for efficiency and effectiveness in the global economy, it is likely that the rapid pace of organizational change will continue or even quicken (Salas & Cannon-Bowers, 2000). In addition, organizations are quickly becoming interested in using technology to distribute learning and reduce training costs (Bell & Kozlowski, in press; Brown, 2001). These and other factors will increase the need for employees who possess generalizable skills and knowledge and place a greater premium on training techniques that can effectively harness the active learning inherent in relative autonomous and unstructured distributed training environments (Brown & Ford, 2002). It has been argued that active learning techniques, such as error training, mastery training, and guided exploration, may be well suited for these challenges. The results of the present study provided support for this contention and showed that error training generally enhanced trainees' knowledge and skills.

At the same time, however, it is important to recognize that the effectiveness of error training and similar instructional strategies is likely to depend on a number of factors, such as trainee characteristics, the nature of desired knowledge and skills, and the training and organizational context. The present study suggests that error training may be more appropriate when the goal of training is to develop flexible and adaptable skills, learning activities are more complex and not easily translated into proceduralized instructions, and trainees have low levels of performance-avoid orientation. It will be critical for organizations to carefully consider these issues when deciding whether or not error training makes sense in a given situation. As research and theory continues to

develop around active learning, we should gain a better understanding of the conditions under which these instructional strategies will be most effective.

Finally, the present study adds to a growing line of research that implicates a number of individual differences as critical in training. These individual differences include not only cognitive ability but also personality traits, such as openness and conscientiousness, and dispositions, such as goal orientation. The present study found that these individual differences had a considerable influence on the training processes and outcomes examined. Essentially, it appears that individuals who possess certain characteristics are naturally more active learners. Organizations may benefit, therefore, by including these individual differences in the needs assessment process and incorporating them into selection systems. In addition, the increased use of computer technologies in training provides unprecedented capability to design training that adapts to individual differences in learners. Thus, it will be important to further explore aptitude x treatment interactions in future training research.

Conclusion

The present study was designed to tease apart the instructional, motivational, and emotional elements of error training and examine their independent and interactive effects on an array of training outcomes. In addition, this study assessed the impact of these elements on numerous cognitive, affective, and behavioral mechanisms and explored the role of individual differences in error training. It was found that the instructional and motivational elements significantly influenced trainees' knowledge and generalization performance. In addition, each of the elements influenced a specific set of training processes. Exploratory learning increased trainees' cognitive activity, error

encouragement interacted with exploratory learning to enhance trainees' intrinsic motivation, and the emotion-control training lowered individuals' state anxiety and increased their self-efficacy. The effects of the error training elements were also partially dependent on a number of the individual differences. Cognitive ability and trait goal orientation appear to be particularly important for determining the effectiveness of error training, although trait anxiety, openness, and conscientiousness may also be important to consider. Overall, this study contributes to our understanding of error training as well as other active learning techniques that share similar underlying elements. Future research should expand on these findings in an effort to maximize the potential inherent in active learning for helping modern organizations address their training needs.

FOOTNOTES

¹ The measure of self-evaluation activity was not included in the original proposal. In addition, it was originally proposed that cognitive effort would be assessed through a self-report measure. In the proposal meeting, however, several committee members suggested that it would be advantageous to supplement the self-report cognitive measures with more objective measures. Thus, the measures of self-evaluation activity and cognitive effort were created from information collected through the feedback program and on-line training manual, respectively, in an attempt to follow this suggestion.

² Principal components factor analyses were conducted on the basic and strategic performance indicators at four time periods: third training trial, ninth training trial, near transfer trial, far transfer trial. At all four time periods, the basic and strategic performance indicators loaded cleanly onto separate factors. In general, the loadings of variables on their respective components were greater than $\pm .70$ and cross loadings were less than $\pm .30$. It should be noted that initially only one factor was extracted in the analyses conducted in the far transfer trial. This was due to the fact that the second factor had an eigenvalue of .884 and, therefore, did not meet the Kaiser normalization criteria of rotating factors with eigenvalues greater than 1.0. However, when a two-factor solution was forced, the results were consistent with those for the other three time periods.

³ The MANOVA examined the overall effects of the error training elements on all of the training processes and outcomes of interest. These include individuals' basic, strategic, and overall performance at the end of training and in the near and far transfer trials, trainees' basic and strategic knowledge both early and later in training, and the

various instructional, motivational, and emotional training processes as measured at the end of training.

⁴ The analyses were also conducted with the full set of individual differences included in the first step of the regression. The substantive conclusions drawn from the analyses with the full and reduced sets of individual differences were virtually the same.

⁵ Before each of the three training sessions, participants were given a list of learning objectives or training topics. In addition, common errors associated with the objectives were discussed. The proceduralized instruction was designed to minimize these errors. Furthermore, the error encouragement directions encouraged trainees to make these errors and the error avoidance directions told individuals to avoid these errors. Data collected from the task was used to examine the extent to which individuals exhibited these errors. Error indicators were created for each session and were summed to create an overall error index or composite.

⁶ In a few cases, participants allowed the feedback program to run beyond the designated 90 seconds. This was most likely to occur during the final trial of each block, because at these points in the training the experimenter did not provide timed instructions for participants to advance to the next computer screen. When participants had a non-valid value (e.g., greater than 90 seconds) for time spent on the feedback screen, the value was recoded as missing. The average time each participant spent on the final feedback screens during the six trials was then calculated from valid, non-missing values.

⁷ Baron and Kenny (1986) focus on situations where there is a single predictor, mediator, and outcome. Conducting individual analyses for each predictor and mediator in the current study is not feasible. Thus, a blocked design will be used. This provides a

simplified examination of whether a set of proposed mediators accounts for the variance explained by a set of distal predictors or antecedents. While there is a loss in precision, this method provides an economical alternative when large number of variables are being examined. A good example of this block mediation method is a recent paper by Schmidt and Ford (2001) or a study by Kozlowski and Farr (1988).

⁸ The motivational mediation analyses were also run with state anxiety included as a motivational process variable. This did not alter the results or conclusions.

⁹ Analyses were conducted to explore the potential for curvilinear relationships between state anxiety and knowledge and performance. Support was not found for curvilinear relationships. Across all knowledge and performance outcomes, a linear regression model evidenced better predictive power than a quadratic regression model.

APPENDICES

THE RADAR CONTROL SIMULATION

Want to get a good chunk of your psychology experiment credits taken care of right away?

Want a chance to win some cash?

If so, you should sign up for the Radar Control Simulation. This experiment is available to anyone in PSY 100 or other classes that use the PSY100 subject pool. Here are the details:

Length: ½ hour on-line, and 3 hours in laboratory experiment.

Location: Room 4 Snyder Hall

Credits: 7 Credits

Prizes: 8 cash prizes ranging from \$20 to \$50 for people who display the highest levels of knowledge and performance.

Description: In this experiment you will learn how to operate a radar control simulation developed by the US Navy. You will monitor a radar screen and will need to decide how to deal with the different targets that appear on your screen. You will also answer a few questionnaires related to the simulation.

If interested you should sign up through the PSY100 subject pool web-site. If you want more information contact the experimenter: Brad Bell at 353-9166 or bellbra1@msu.edu. Thanks!

APPENDIX B

Electronic Informed Consent for On-line Questionnaire

Project Title:	The Radar Control Simulation
Investigators' Names:	Bradford S. Bell, Christine Prokopp, & Steve Kozlowski, Ph.D.
Description and Explanation of Procedure:	This study is about computer-based training. The study has two parts. In the first part of the experiment, you will be asked to fill out a questionnaire on the PSY 100 web site. In the second part of the experiment you will go to room 4 Snyder Hall and participate in a computer simulation. This consent form relates to the first part of the research study. If you agree to participate in the first part of the research, you will be asked to fill out an online questionnaire, which will take about 30 minutes. It includes questions about your demographic information, SAT or ACT scores, and other variables related to the computer simulation you will operate if you agree to participate in the second part of the research study.
Estimated time required:	30 minutes
Risks and discomforts:	None
Benefits:	You will gain experience completing several standard psychological measures that are used widely by organizations. In addition, you will gain experience completing these measures on-line, a format used by more and more organizations. Finally, you will learn about the process of conducting psychological research.

You have been fully informed of the above-described procedure with its possible benefits and risks. You will be able to view your responses at a later date and be fully debriefed on them if you so desire. The investigators will be available to answer any questions you may have. If, at any time, you feel your questions have not been adequately answered or you want to discuss the research, please contact the experimenter (Brad Bell, 353-9166) or the Head of the Department of Psychology (Neal Schmitt, 353-9563). If you have questions regarding your role and rights as a subject of research, you may contact David Wright, chair of the University Committee on Research Involving Human Subjects (355-2180), separate from anyone involved in conducting this research project. You are free to withdraw this consent and discontinue participation in this project at any time without penalty. If you choose to withdraw from the study prior to its completion, you will receive credit only for the time you have spent in the study. Within one year of your participation, a copy of this consent form will be provided to you upon request.

If you agree to participate, you will be asked to type your name at the bottom of this form. The reason you are asked for your name is to ensure that you receive credit for participating in the study. Your name will not be associated with your responses, and will be kept confidential. Your privacy will be protected to the maximum extent allowable by law.

Name: _____ Date: _____

APPENDIX C

Informed Consent for the Radar Control Simulation

Project Title:	The Radar Control Simulation
Investigators' Names:	Bradford S. Bell, Christine Prokopp, & Steve Kozlowski, Ph.D.
Description and Explanation of Procedure:	This study examines your learning and performance on a radar control simulation. In this study, you will be trained to operate the radar control simulation and will have a chance to practice in a number of trials. Using the computer-mouse, you will assess the attributes of targets that appear on your screen and decide what actions should be taken for each contact. You will also be asked to answer questions which will help us understand your task performance and learning. You will receive six credits for participation in this study. In addition, you may receive \$25 based on your scores on the final trials. Additional information on the awards is provided on the prize sheet included in this folder. Winners will be determined at the end of the semester and will be contacted so they can claim their prize.
Estimated time required:	3 hours
Risks and discomforts:	None
Benefits:	You will gain experience in a realistic, computer-based training environment. This can be valuable as more and more organizations use computer-based training to teach various knowledge and skills. In addition, you will learn about the process of conducting psychological research.

You have been fully informed of the above-described procedure with its possible benefits and risks. You will be able to view your responses at a later date and be fully debriefed on them if you so desire. The investigators will be available to answer any questions you may have. If, at any time, you feel your questions have not been adequately answered or you want to discuss the research, please contact the experimenter (Brad Bell, 353-9166) or the Head of the Department of Psychology (Neal Schmitt, 353-9563). If you have questions regarding your role and rights as a subject of research, you may contact David Wright, chair of the University Committee on Research Involving Human Subjects (355-2180), separate from anyone involved in conducting this research project. You are free to withdraw this consent and discontinue participation in this project at any time without penalty. If you choose to withdraw from the study prior to its completion, you will receive credit only for the time you have spent in the study. Within one year of your participation, a copy of this consent form will be provided to you upon request.

If you agree to participate, please sign your name at the bottom of this form. We also ask for your e-mail address and phone number so that we can contact you if you win a prize. It is important to recognize that you will be given a subject number for this experiment. The purpose of this subject number is to keep track of the various materials you will complete during the experiment. Your name will not be associated with your responses and all information you give us will be kept confidential.

Name: _____ Date: _____
Signature: _____ Email: _____
Phone: _____

APPENDIX D

SAT/ACT Release Form

When you completed the online questionnaire, we asked you to provide your SAT or ACT score. We recognize, however, that some people took these tests a number of years ago and may not remember their scores. Therefore, we often like to verify these scores with the Registrar's office. To do this, we need your permission to obtain your SAT/ACT scores. This information will be kept completely confidential and will be used only for the purposes of this experiment. We typically only obtain scores from the Registrar's when a person does not remember his or her scores.

By signing below you are providing your consent for us to verify your SAT and/or ACT scores with the Registrars office. Your signature serves as a release of your scores to us for the purpose of this experiment. We ask for your PID so that the Registrar's office can locate your scores in their database. Once again, this information will be kept completely confidential.

If you have any questions, please raise your hand and ask the experimenter or contact the principal investigator at any time: Brad Bell at 353-9166 or bellbra1@msu.edu.

Name: _____ PID: _____

Signature: _____ Date: _____

Appendix E

Example of Feedback

For this practice period:

Number of targets engaged: #

Number of targets engaged correctly: #

Number of targets engaged incorrectly: #

Your total score: ###

Targets that popped-up: 6

Number of pop-up targets you engaged: #

Percentage of pop-up targets you engaged: #%

Press any key to continue . . .

Appendix F

Debriefing Sheet

The Radar Control Simulation

The study in which you just participated was designed to examine the effects of different training methods on individuals' learning and performance. During this study, you operated a radar simulation known as TANDEM. TANDEM simulates the complex physical performance, information processing, and decision-making demands of performing fast-paced, critical tasks. To perform the TANDEM simulation, you needed to learn how to operate the task and develop strategies for effective task performance. TANDEM required you to gather information about the objects on the screen, make decisions, and take actions based on the information you gathered. We will use the information gathered during the study to link your performance on the task to your knowledge of the task. In addition, we will examine whether different training methods, such as guiding individuals through the task or allowing them to explore the task on their own, have different effects on these outcomes.

If you have any questions about this study or would like to receive a copy of the results when they are complete, please notify the investigator now. If, in the future, you have any questions about the study or would like to receive the results when they are complete, please call the investigator listed below. Finally, thank you for participating in this study. If you have any other questions or comments please do not hesitate from contacting the experimenter.

Investigator: Brad Bell 353-9166 or bellbra1@msu.edu

APPENDIX G

Description of Prizes

We will award a total of eight cash prizes to the best players. Two categories of proficiency will be recognized, and four awards will be offered in each category:

Two 1st place prizes at \$50 each
Two 2nd place prizes at \$40 each
Two 3rd place prizes at \$30 each
Two 4th place prizes at \$20 each

Each set of four awards will be made for different types of game proficiency:

One pair of awards will be made for the players who understand the game the best during the three practice sessions. You will answer several questionnaires about the game during and after the practice sessions. You need to think carefully about your answers to the questions. The top players who answer these questions the best will be awarded 1st, 2nd, 3rd, and 4th place prizes.

The second pair of awards will be made for the players who do the best on the final two trials that will take place at the end of the experiment. The top players who do the best will be awarded 1st, 2nd, 3rd, and 4th place prizes. I will let you know when the final trials are about to begin.

The Prizes are independent of each other. That means its possible to be awarded prizes in both categories of proficiency. Your chances of getting an award are pretty good – it's all up to you.

APPENDIX H

Practice Topics

Training Topics for Training Block 1

In this first block of three trials, the major focus of training is getting familiar with the simulation and making target decisions. You should focus on the following training topics:

1. Using the mouse and other equipment to operate the simulation.
2. Hooking targets and accessing the pull down menus.
3. Making TYPE target decisions.
4. Making CLASS target decisions.
5. Making INTENT target decisions.
6. Making FINAL ENGAGEMENT target decisions.
7. Viewing right button feedback after making target decisions.

Training Topics for Training Block 2

In this second block of three trials, the major focus of training is preventing targets from crossing the defensive perimeters. You should focus on the following training topics:

1. Using the zoom function to view the “big picture” and monitor the inner and outer perimeters.
2. Using marker targets to locate the outer defensive perimeter.
3. Watching for pop-up targets that appear suddenly on your screen.

Training Topics for Training Block 3

In this last block of practice trials, the major focus of training is being able to apply strategies that are used to better prevent targets from crossing the defensive perimeters. You should focus on the following training topics:

1. Prioritizing targets located on the radar screen to determine high and low priority targets and the order in which targets should be prosecuted.
2. Making trade-offs between targets that are approaching your inner and outer defensive perimeters.

APPENDIX I

Exploratory Learning Instructions

Task Instructions – Block 1

An effective method for learning the skills just discussed is to explore the task and develop your own understanding of it. As you practice the scenarios, explore the task to understand what is occurring in the scenario, and to discover the best strategy to deal with the situation. Also, experiment with different strategies and methods as you explore the task and learn important task skills. Remember, your task is to learn the basic features of the simulation, hook targets and use pull-down menus, make target decisions, and view right-button feedback following target decisions.

Task Instructions – Block 2

An effective method for learning the skills just discussed is to explore the task and develop your own understanding of it. As you practice the scenarios, explore the task to understand what is occurring in the scenario, and to discover the best strategy to deal with the situation. Also, experiment with different strategies and methods as you explore the task and learn important task skills. Remember, your task is to learn how to prevent targets from crossing your perimeters. To do this effectively, you will need to learn how to use the zoom function, how to use marker targets to locate the outer defensive perimeter, and how to watch for pop-up targets that appear suddenly on your screen.

Task Instructions – Block 3

An effective method for learning the skills just discussed is to explore the task and develop your own understanding of it. As you practice the scenarios, explore the task to understand what is occurring in the scenario, and to discover the best strategy to deal with the situation. Also, experiment with different strategies and methods as you explore the task and learn important task skills. Remember, your task is to learn how to prioritize targets and make tradeoffs between targets that are approaching your inner and outer perimeters.

APPENDIX J

Proceduralized Instructions

Task Instructions – Block 1

During each of the first three trials, there will be 22 targets on the radar screen. When you start each trial, you will see a number of these targets on the screen. Since your focus is on learning basic features of the task and making target decisions, you should focus on these targets for now. After the experimenter instructs you to start the scenario and the timer begins to count down, you will focus on hooking targets, making decisions about the targets, and viewing feedback about your decisions. You should follow the instructions below for Trials 1, 2, & 3. During these trials, you should follow the following steps:

1. Hook a target of your choice.
 - a. Using the mouse, place the arrow on a target and click the left mouse button.
 - b. When the target is properly hooked, it will turn green and the Hooked Track # in the lower right corner of your radar screen changes to correspond to the target number.
 - c. When you gather information from your ship's sensors, that information will be given for the target you currently have hooked.
2. Make TYPE, CLASS, INTENT sub-decisions for hooked targets.
 - a. After the target is hooked, place the arrow on the TYPE menu button located in the top right of your radar screen. Click on the right mouse button to display the menu options.
 - b. Move your arrow to the button that says "Speed" and click and hold the right mouse button to view the target's speed. Use the chart on the next page to see what type of target is indicated by the speed information. After viewing target speed, do the same for "Altitude/Depth" and "Communication Time." Once again, use the chart on the next page to see what type of target is indicated by the cue values. Note that one value you gathered may be inconsistent with the other two; if this is the case choose the option indicated by the majority (2 out of 3) of the values.
 - c. After viewing the three pieces of information, you are ready to make the TYPE decision. Choose "ID_Air/Sub/Surface" from the bottom of the TYPE menu.
 - d. A list of choices appears in a menu on the lower right corner of your radar screen. Choose the option that was indicated by the majority of the cues you collected by clicking your right mouse button on the option.
 - e. Perform steps a through d for the CLSS decision and then the ITNT decision.
3. Make FINAL ENGAGEMENT decision.
 - a. After you have made the TYPE, CLASS, and INTENT decisions for a target, you can then make the final engagement decision.
 - b. Move your arrow to OPER menu and click the right mouse button.
 - c. Move your arrow to the menu option that says "Engage_Shoot/Clear" and click the right mouse button. A list of choices appears in the lower right corner of your radar screen.
 - d. If the INTENT of the target was peaceful you should click your right mouse button on the "clear" option, but if the INTENT of the target was hostile you should click your right mouse button on the "shoot" option. See next step before doing this.
 - e. When you click your right mouse button on either "clear" or "shoot" you can hold it down to receive information on whether you have engaged the target correctly.
4. REPEAT
 - a. After you make the final engagement decision, the target will disappear and you should repeat steps 1 – 3 for another target.
 - b. If you eliminate all targets in your viewing range, place your arrow on the OPER menu and click the right mouse button. Then place the arrow on the "Zoom-out" option and click your right mouse button. When you do this, more targets should appear and you can continue.

Target Cue Values

Listed below are the cue values for different types of targets. Remember, as you make TYPE, CLASS, and INTENT decisions you want to select the option indicated by the MAJORITY of the cue values. Note: you will not be able to use this sheet in the final two trials.

TARGET TYPE	
AIR	Speed = > 35 knots Altitude/Depth = > 0 feet Communication Time = 0 – 40 s
SURFACE	Speed = 25 – 35 knots Altitude/Depth = 0 feet Communication Time = 41 – 80 s.
SUB	Speed = 0 – 24 knots Altitude/Depth = < 0 feet Communication Time = 81 – 120 s.

TARGET CLASS	
CIVILIAN	Intelligence = Private Direction of origin = Blue Lagoon Maneuvering pattern = Code Foxtrot
UNKNOWN	Intelligence = Unavailable Direction of origin = Unknown Maneuvering pattern = Code Echo
MILITARY	Intelligence = Platform Direction of origin = Red Sea Maneuvering pattern = Code Delta

TARGET INTENT	
PEACEFUL	Countermeasures = None Threat Level = 1 Response = Given
UNKNOWN	Countermeasures = Unknown Threat Level = 2 Response = Inaudible
HOSTILE	Countermeasures = Jamming Threat Level = 3 Response = No Response

FINAL ENGAGEMENT DECISION	
CLEAR	If INTENT = Peaceful
SHOOT	If INTENT = Hostile

Task Instructions – Block 2

During next three trials, there will be 22 targets on the radar screen. A number of these targets surround your inner defensive perimeter and a number surround your outer defensive perimeter. Your primary task during these trials is to prevent targets from crossing your defensive perimeters. To do this, you will need to use the zoom function, hook marker targets, and monitor your screen for pop-up targets.

The instructions below will guide you step-by-step through the next three trials and will instruct you on how to use the zoom function, hook marker targets, deal with threatening pop-up targets, and protect your perimeters. In each of the trials, the targets are distributed differently so you have separate instructions for Trials 4, 5, and 6. After the experimenter instructs you to start the simulation and the time begins counting down, you should follow the instructions for the respective trial. If you follow these instructions, you will prevent the majority of perimeter intrusions.

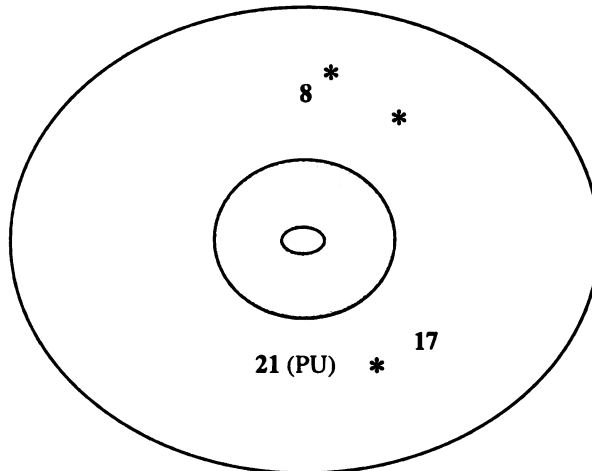
Instructions for Trial 4

1. Hook and prosecute Target #17.
 - On the next page, see the diagram for your current viewing range, which is 32 nm.
 - Target #17 is identified on that diagram.
 - Using the instructions given to you in the first training session, hook and prosecute Target #17. You can be sure you dealing with Target #17 by examining the Hooked Track display in the lower right corner of your radar screen.
2. Hook and prosecute Target #8.
 - Follow the same steps as above, but this time for Target #8.
3. Hook and prosecute Pop-Up Target #21.
 - Follow the same steps as above, but this time for Pop-Up target #21. If this target is not visible yet, it should appear on your screen at any moment.
4. Hook Marker Target #2.
 - First, in the OPER menu, place the arrow on the “Zoom-out” option and click your right mouse button three times.
 - Your current viewing range should be 256 nm. You can check this in the range indicator in the bottom left corner of your radar screen.
 - Hook Marker target #2. Target #2 is located at the bottom middle of your radar screen at about 180°. You can also determine its location from the diagram for 512 nm on the next page.
 - Do not make any decisions for this target.
 - In the OPER menu, place the arrow on the “Zoom-out” option and click on your right mouse button once to zoom out to 512nm.
5. Hook and prosecute Target #9.
 - Locate target #9 on the diagram for your current viewing range, which is 512nm.
 - Using the instructions given to you in the first training session, hook and prosecute Target #9.
6. Hook and prosecute Target #5.
 - a. Use the diagram for 512 nm to locate this target.
 - b. Hook and prosecute this target using the instructions given to you in the first training session.
8. Hook and prosecute Pop-Up Target #20.
 - a. Using the diagram for 512nm, locate Pop-Target #20.
 - b. Hook and prosecute this target using the instructions given to you in the first training session.

9. Hook and prosecute Pop-Up Target #22
 - a. Using the diagram for 512nm, locate Pop-Target #20.
 - b. Hook and prosecute this target using the instructions given to you in the first training session.
10. Hook and prosecute Target #3.
 - a. Using the diagram for 512nm, locate Target #3.
 - b. Hook and prosecute this target using the instructions given to you in the first training session.
11. If there is still time remaining, hook and prosecute a target of your choice.

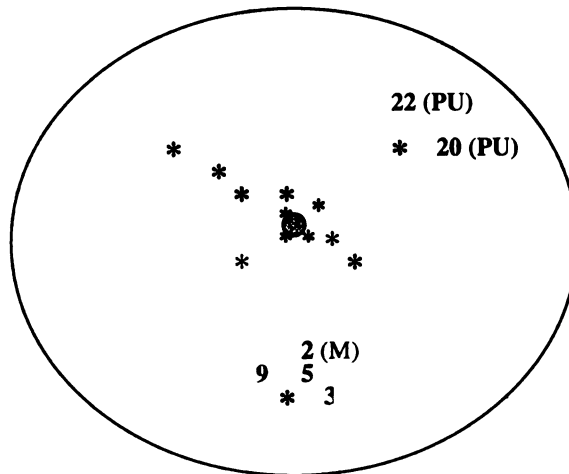
32 nm

PU = Pop-up Target
M = Marker Target



512 nm

PU = Pop-up Target
M = Marker Target



Task Instructions – Block 3

During next three trials, there will be 22 targets on the radar screen. Once again, a number of these targets surround your inner defensive perimeter and a number surround your outer defensive perimeter. Your task during the next three trials is locate high priority targets and make trade-offs between targets approaching your inner and outer defensive perimeters.

The instructions below will guide you through each of the three upcoming trials and will instruct you on how to prosecute high priority targets and how to make target trade-offs. Once again, the targets are distributed differently across the various trials. So, you have separate instructions for trials 7, 8, and 9. After the experimenter instructs you to start the simulation and the time begins counting down, you should follow the instructions for the respective trial. If you follow these instructions, you will prosecute the majority of the high priority targets. You will also effectively make trade-offs between targets approaching your inner and outer perimeters and minimize the number of targets that cross your perimeters.

Instructions for Trial 7

1. Hook and prosecute High-Priority Target #17.
 - On the next page, see the diagram for your current viewing range, which is 32 nm.
 - High priority target #17 is identified on that diagram.
 - Using the instructions given to you in the first training session, hook and prosecute Target #17. You can be sure you dealing with Target #17 by examining the Hooked Track display in the lower right corner of your radar screen.
2. Hook and prosecute High-Priority Target #15.
 - Follow the same steps as above, but this time for High-Priority Target #15.
3. Check the speed of Target #12
 - Using the diagram on the next page for 32nm, locate target #12.
 - Hook this target and check the speed of the target in the TYPE menu.
 - Do not prosecute this target.
4. Hook and prosecute High-Priority Target #4.
 - Locate high-priority target #4 on the diagram for your current viewing range, which is 32nm.
 - Using the instructions given to you in the first training session, hook and prosecute Target #4.
5. Check the speed of Target #19
 - Using the diagram on the next page for 32nm, locate target #19.
 - Hook this target and check the speed of the target in the TYPE menu.
 - Do not prosecute this target.
6. Hook Marker Target #9.
 - First, in the OPER menu, place the arrow on the “Zoom-out” option and click your right mouse button three times.
 - Your current viewing range should be 256 nm. You can check this in the range indicator in the bottom left corner of your radar screen.
 - Hook Marker target #9. Target #9 is located at the top right of your radar screen at about 60°. You can also determine its location from the diagram for 512 nm on the next page.
 - Do not make any decisions for this target.
 - In the OPER menu, place the arrow on the “Zoom-out” option and click on your right mouse button once to zoom out to 512nm.
7. Hook and prosecute High-Priority Target #18.

- Locate high-priority target #18 on the diagram for your current viewing range, which is 512nm.
- Using the instructions given to you in the first training session, hook and prosecute Target #18.

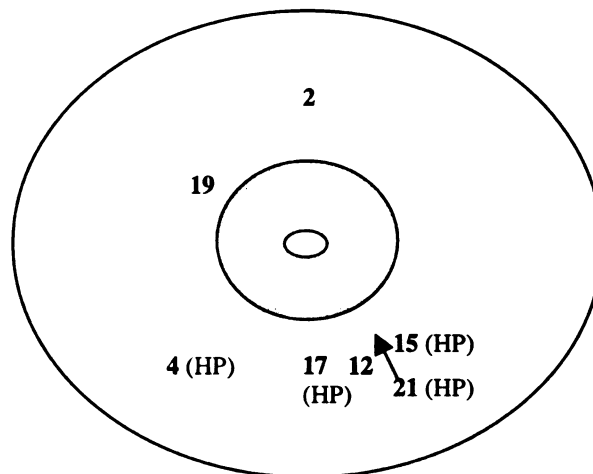
8. Hook and prosecute High Priority Target #21.

- In the OPER menu, place the arrow on the “Zoom-in” option and click your right mouse button four times to zoom in to 32nm.
- On the next page, see the diagram for your current viewing range, which is 32nm.
- Using the instructions given to you in the first training session, hook and prosecute High Priority Target #21. If this target is not visible yet, it should appear on your screen at any moment.

9. If there is still time remaining, hook and prosecute a target of your choice.

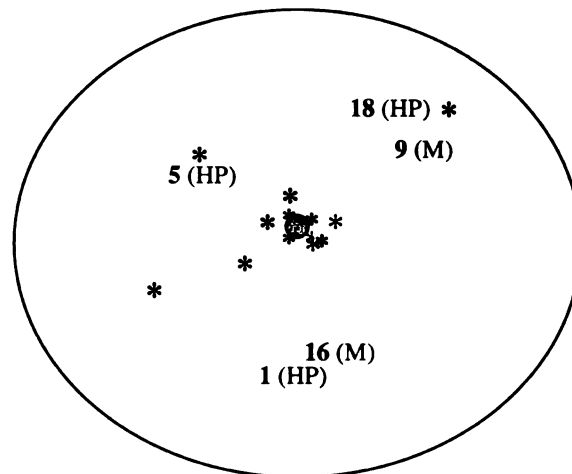
32 nm

M = Marker Target
HP = High Priority



512 nm

M = Marker Target
HP = High Priority



APPENDIX K

Error Instructions

Error Encouragement – Block 2

For each of the training topics listed above, there is the potential for a number of errors. Some of the common mistakes in these areas are listed below:

1. Focusing on only the inner perimeter rather than zooming out to see the “big picture” and to monitor the outer perimeter.
2. Hooking the wrong marker targets or not using marker targets to locate the outer perimeter.
3. Focusing only on stable targets and ignoring targets that pop-up suddenly on the screen. Often people do not monitor their screen for pop-up targets.
4. Letting targets cross the inner and outer defensive perimeters.

During training, you are encouraged to make these errors. For training to be effective, you should make these errors. Errors are a positive part of the learning experience. As a result of making errors, you can learn from your mistakes and develop a better understanding of the simulation. The more errors you make the more you learn.

Error Avoidance – Block 2

For each of the training topics listed above, there is the potential for a number of errors. Some of the common mistakes in these areas are listed below:

1. Focusing on only the inner perimeter rather than zooming out to see the “big picture” and to monitor the outer perimeter.
2. Hooking the wrong marker targets or not using marker targets to locate the outer perimeter.
3. Focusing only on stable targets and ignoring targets that pop-up suddenly on the screen. Often people do not monitor their screen for pop-up targets.
4. Letting targets cross the inner and outer defensive perimeters.

During training, you are encouraged to avoid these errors. For training to be most effective, you should try not to make these errors. Errors are detrimental to the learning process and will hurt your understanding of the simulation. The more errors you avoid the more you learn.

Appendix L
Error Feedback

Training Block 2

Listed below is information that will allow you to determine whether you made errors on the training topics for this session. If you did not commit any errors in a particular area the feedback will indicate this.

You did not zoom out

You did not hook any of the marker targets

You only prosecuted X out of 4 pop-up targets

You allowed X inner penalty intrusions

You allowed X outer penalty intrusions

Appendix M

Emotion-control Statements

As you practice the radar control simulation, you may experience anxiety or frustration. Don't worry, this is common and many people experience these emotions. However, it is also important to recognize that these emotions can hurt your learning and performance. When people become anxious or frustrated, they tend to focus on their emotions rather than the task at hand.

Often, people become frustrated during training and engage in negative and self-defeating thoughts such as "I am an idiot" or "I will never be able to do this." These are negative and irrational thoughts that increase a person's level of anxiety.

To prevent negative emotions, you should engage in positive and constructive self-talk. Listed below are several examples of positive and rational statements. These statements can help you avoid negative thoughts and can help you adopt a positive "CAN DO" attitude. You can certainly use other positive or rational statements that you think will work well for you. Periodically throughout training you should repeat these statements silently to yourself. In particular, you should repeat these or similar positive statements to yourself when you notice you are getting frustrated or anxious. This will help you to stay focused on the task and will increase your learning and performance.

- Remember, worry won't help anything.
- It is okay if I am not doing as well as I would like. I can always improve.
- This task may be challenging, but I know I CAN do it.
- I can use my past experiences on this task as opportunities for improvement.
- I am focused and I know I will succeed.

APPENDIX N
On-line Questionnaire

SAT and ACT Scores

In the spaces below, please provide your highest SAT and/or ACT score. It is important to realize that this score will be used for research purposes only and will be kept confidential. If you do not remember your score, please put a zero in space for the SAT score.

SAT Score: _____

ACT Score: _____

Button et al. (1996) Trait Goal Orientation Measure

This set of questions asks you describe your task orientation. Please make your ratings by clicking on one of the buttons below each question.

1	2	3	4	5	6	7
strongly disagree	moderately disagree	slightly disagree	neither agree nor disagree	slightly agree	moderately agree	strongly agree

1. I prefer to do things that I can do well rather than things that I do poorly.
2. I'm happiest at work when I perform tasks on which I know I won't make any errors.
3. The things I enjoy the most are the things I do the best.
4. The opinions others have about how well I do certain things are important to me.
5. I feel smart when I do something without making any mistakes.
6. I like to be fairly confident that I can successfully perform a task before I attempt it.
7. I like to work on tasks that I have done well on in the past.
8. I feel smart when I can do something better than most other people.
9. The opportunity to do challenging work is important to me.
10. When I fail to complete a difficult task, I plan to try harder the next time I work on it.
11. I prefer to work on tasks that force me to learn new things.
12. The opportunity to learn new things is important to me.
13. I do my best when I'm working on a fairly difficult task.
14. I try hard to improve on my past performance.
15. The opportunity to extend the range of my abilities is important to me.
16. When I have difficulty solving a problem, I enjoy trying different approach to see which one will work.

VandeWalle (1997) Trait Goal Orientation Measure

This set of questions asks you describe your general work orientation. Please make your ratings by clicking on one of the buttons below each question.

1	2	3	4	5	6
strongly disagree	moderately disagree	slightly disagree	slightly agree	moderately agree	strongly agree

- 17. I am willing to select a challenging assignment that I can learn a lot from.
- 18. I often look for opportunities to develop new skills and knowledge.
- 19. I enjoy challenging and difficult tasks where I'll learn new skills.
- 20. For me, development of my ability is important enough to take risks.
- 21. I prefer situations that require a high level of ability and talent.
- 22. I'm concerned with showing that I can perform better than others.
- 23. I try to figure out what it takes to prove my ability to others.
- 24. I enjoy it when others are aware of how well I am doing.
- 25. I prefer projects where I can prove my ability to others.
- 26. I would avoid taking on a new task if there were a chance that I would appear rather incompetent to others.
- 27. Avoiding a show of low ability is more important to me than learning a new skill.
- 28. I'm concerned about taking on a task at work if my performance would reveal that I had low ability.
- 29. I prefer to avoid situations where I might perform poorly.

Conscientiousness & Openness to Experience

Please indicate how much each of the following statements describes you using the scale below:

1	2	3	4	5	6	7
strongly disagree	moderately disagree	slightly disagree	neither agree nor disagree	slightly agree	moderately agree	strongly agree

- 30. I keep my belongings clean and neat.
- 31. I'm pretty good about pacing myself so as to get things done on time.
- 32. I am not a very methodical person.
- 33. I try to perform all the tasks assigned to me conscientiously.
- 34. I have a clear set of goals and work toward them in an orderly fashion.
- 35. I waste a lot of time before settling down to work.
- 36. I work hard to accomplish my goals.

37. When I make a commitment, I can always be counted on to follow through.
38. Sometimes I'm not as dependable or reliable as I should be.
39. I am a productive person who always gets the job done.
40. I never seem to be able to get organized.
41. I strive for excellence in everything I do.
42. I don't like to waste my time daydreaming.
43. Once I find the right way to do something, I stick to it.
44. I am intrigued by the patterns I find in art and nature.
45. I believe letting students hear controversial speaks can only confuse and mislead them.
46. Poetry has little or no effect on me.
47. I often try new and foreign foods.
48. I seldom notice the moods or feelings that different environments produce.
49. I believe we should look to our religious authorities for decisions on moral issues.
50. Sometimes when I am reading poetry or looking at a work of art, I feel a chill or wave of excitement.
51. I have little interest in speculating on the nature of the universe or the human condition.
52. I have a lot of intellectual capacity.
53. I often enjoy playing with theories or abstract ideas.

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Trait Anxiety

A number of statements which people have used to describe themselves are given below. Read each statement and then click the appropriate button under the statement to indicate how you **generally** feel. There are no right or wrong answers. Do not spend too much time on any one statement, but give the answer which seems to describe how you generally feel.

1	2	3	4
Almost Never	Sometimes	Often	Almost Always

54. I feel pleasant.
55. I feel nervous and restless.
56. I feel satisfied with myself.
57. I wish I could be as happy as others seem to be.
58. I feel like a failure.
59. I feel rested.

- 60. I am "calm, cool, and collected."
- 61. I feel that difficulties are piling up so that I cannot overcome them.
- 62. I worry too much over something that really doesn't matter.
- 63. I am happy.
- 64. I have disturbing thoughts.
- 65. I lack self-confidence.
- 66. I feel secure.
- 67. I make decisions easily.
- 68. I feel inadequate.
- 69. I am content.
- 70. Some unimportant thought runs through my mind and bothers me.
- 71. I take disappointments so keenly that I can't put them out of my mind.
- 72. I am a steady person.
- 73. I get in a state of tension or turmoil as I think over my recent concerns and interests.

Demographics

The questions below ask you to provide some basic information about yourself.
Answer the questions by clicking on the appropriate button.

74. What is your gender?

- (1) Male (2) Female

75. What is your age?

- (1) < 18 yrs (2) 18- 19 yrs (3) 20 - 21 yrs (4) 22-23 yrs (5) > 23 yrs

76. What is your overall grade point average?

- (1) 0 - 1.0 (2) 1.1 - 2.0 (3) 2.1 - 3.0 (4) 3.1 - 4.0 (5) > 4.0

77. Do you play with video games?

- (1) Never (2) Rarely (3) Sometimes (4) Frequently (5) Always

APPENDIX 0

Measures Assessed During Experiment

Hypothesis Testing

Please answer the following activities during the practice sessions. Use the following rating scale to indicate your agreement with each of the following statements:

1	2	3	4	5	6	7
strongly disagree	moderately disagree	slightly disagree	neither agree nor disagree	slightly agree	moderately agree	strongly agree

1. Before practicing a new scenario, I made predictions concerning the challenges I might encounter in the scenario.
2. I identified strategies for dealing with challenges that might occur in the scenario.
3. I explored the task to test my predictions about what the scenario would be like.
4. I watched what occurred at both the inner and outer penalty circle to develop a good understanding of how each scenario would unfold.
5. I experimented with different task strategies to handle the challenges I faced in the scenarios.
6. I thought about how well my predictions about a scenario matched the actual events that occurred during the scenario.

Metacognitive Activity

For each of the items below, rate the extent to which you were thinking about these issues during the practice sessions. Please use the scale shown below to make your ratings and make your ratings on the scantron sheet.

1	2	3	4	5
Never	Rarely	Sometimes	Frequently	Constantly

7. While practicing the simulation, I monitored how well I was learning its requirements.
8. I thought carefully about my performance on the previous trial before selecting what to study and practice.
9. As I performed in the practice trials, I evaluated how well I was learning the skills of the simulation.
10. When my methods were not successful, I experimented with different procedures for performing the task.

11. I considered the skills that needed the most work when choosing what to study and practice.
12. I tried to monitor closely the areas where I needed the most study and practice.
13. I noticed where I made the most mistakes during practice and focused on improving those areas.
14. I carefully determined what to study and practice in order to improve on weaknesses identified in previous trials.
15. I used my performance on the previous trial to revise how I would approach the task on the next trial.
16. I thought about new strategies for improving my performance.
17. I thought ahead to what I would do next to improve my performance.
18. I told myself things to encourage me to try harder.

Cognitive Effort

This set of questions asks you about how much mental effort you put into the task during the last session. Please use the scale below to make your ratings on the scantron sheet.

- | | | | | |
|----------------------|----------|---------------|----------|-------------------|
| 1 | 2 | 3 | 4 | 5 |
| Strongly
Disagree | Disagree | Neither Agree | Agree | Strongly
Agree |

19. I felt mentally tired and worn out after performing the simulation.
20. Learning the simulation was a difficult and complex task.
21. The overall mental workload I felt while learning the simulation was low.
22. Learning the simulation was easy.
23. Learning the simulation required a lot of mental activity.
24. I had to work very hard to learn the simulation.

State Goal Orientation

This set of items asks you a few questions about the task and your feelings throughout training. Please use the scale shown below to make your ratings and make your ratings using the scantron sheet provided earlier.

- | | | | | |
|----------------------|----------|---------------|----------|-------------------|
| 1 | 2 | 3 | 4 | 5 |
| Strongly
Disagree | Disagree | Neither Agree | Agree | Strongly
Agree |

25. On this task, I would like to hide from others that they are better than me.
26. On this task, I would like to avoid situations where I might demonstrate poor performance to myself.
27. On this task, I try [would like] to avoid discovering that others are better than me.

28. I am reluctant to ask questions about this task because others may think I'm incompetent.
29. It is important to me to perform better than others.
30. It is important to me to impress others by doing a good job on this task.
31. I want the experimenters and other students to recognize that I am one of the best on this task.
32. I want to show myself how good I am on this task.
33. I prefer to work on aspects of this task that force me to learn new things.
34. I am willing to work on challenging aspects of this task that I can learn a lot from.
35. The opportunity to learn new things about this task is important to me.
36. The opportunity to work on challenging aspects of this task is important to me.
37. On this task, my goal is to avoid performing poorly.
38. On this task, my goal is perform well.
39. On this task, my goal is learn the task as well as I can.

Intrinsic Motivation

These questions ask you how much you enjoyed performing the task in the previous three sessions. For each of the following statements, please indicate how true it is for you, using the following scale:

1	2	3	4	5	6	7
Not at all			Somewhat			Very
True			True			True

40. I enjoyed doing this activity very much.
41. This activity was fun to do.
42. I thought this was a boring activity.
43. This activity did not hold my attention at all.
44. I would describe this activity as very interesting.
45. I think this activity was quite enjoyable.
46. While I was doing this activity, I was thinking about how much I enjoyed it.

Self-Efficacy Scale

This set of questions asks you to describe how you feel about your capabilities for performing the simulation. Please use the scale shown below to make your ratings.

1	2	3	4	5
Strongly	Disagree	Neither Agree	Agree	Strongly
Disagree				Agree

46. I can meet the challenges of this simulation.
47. I am confident in my understanding of how information cues are related to decisions.

- 48. I can deal with decisions under ambiguous conditions.
- 49. I am certain that I can manage the requirements of this task.
- 50. I believe that I will fare well in this task if the workload is increased.
- 51. I am confident that I can cope with this simulation if it becomes more complex.
- 52. I believe I can develop methods to handle changing aspects of this task.
- 53. I am certain I can cope with task components competing for my time.

State Anxiety

For each of the following statements, please indicate how true it is for you, using the following scale:

1	2	3	4	5	6	7
Not at all True			Somewhat True			Very True

- 54. I did not feel nervous at all while doing the task.
- 55. I felt very tense while doing this activity.
- 56. I was very relaxed while doing this activity.
- 57. I was anxious while working on this task.
- 58. I felt pressured while doing this activity.

Attributions – Feelings of Control

Think about the reasons for your performance. The items below concern your impressions or opinions of the cause or causes of your performance. Select the number that best represents your impressions or opinions.

Is the cause(s) something:

- 59. Manageable by you 9 8 7 6 5 4 3 2 1 not manageable by you
- 60. You can regulate 9 8 7 6 5 4 3 2 1 you cannot regulate
- 61. Over which you have power 9 8 7 6 5 4 3 2 1 over which you have no power

Knowledge Test

The following is a knowledge test about the simulation. Please use the Scantron sheet to answer the following questions. Bubble in the correct letter for each question, making sure the question numbers match.

62. If a Response is Given, what is the likely Intent of the target?

- a. Military
- b. Hostile
- c. Civilian
- d. Peaceful

63. A submarine may have which of the following characteristics?

- a. Speed 30 knots, Altitude/Depth - 20, Communication time 85 seconds.
- b. Speed 30 knots, Altitude/Depth 0, Communication time 30 seconds.
- c. Speed 20 knots, Altitude/Depth 0, Communication time 80 seconds.
- d. Speed 20 knots, Altitude/Depth -20, Communication time 90 seconds.

64. A Maneuvering Pattern of Code Delta indicates the target is which of the following?

- a. Air
- b. Military
- c. Surface
- d. Civilian

65. A Blue Lagoon Direction of Origin indicates the target is which of the following?

- a. Unknown
- b. Sub
- c. Civilian
- d. Military

66. If a target's Altitude/Depth is 10 feet, what is the Type of the target?

- a. Air
- b. Surface
- c. Submarine
- d. Unknown

67. If a target's Intelligence is Unavailable, what Class does this suggest for the target?
- a. Air
 - b. Civilian
 - c. Military
 - d. Unknown
68. If a target's characteristics are Communication Time = 20 seconds and Speed = 50 knots, which of the following actions should you take?
- a. Choose Intent is Peaceful
 - b. Choose Type is Surface
 - c. Get another piece of information
 - d. Choose Type is Air
69. A Communication Time of 52 seconds indicates that the target is likely:
- a. Air
 - b. Surface
 - c. Submarine
 - d. Unknown
70. If a target's characteristics are Intelligence is Private and Maneuvering Pattern is Code Foxtrot, which of the following actions should you take?
- a. Choose Class is Military
 - b. Choose Intent is Peaceful
 - c. Choose Class is Civilian
 - d. Choose Intent is Unknown
71. If a target's Maneuvering Pattern is Code Echo, this suggests that the target falls into which category?
- a. Class is unknown.
 - b. Class is Military
 - c. Class is Hostile
 - d. Class is Peaceful

72. If a target's Speed is 40 knots, what does this suggest about the target?
- a. The target is Air.
 - b. The target is Surface.
 - c. The target is Civilian
 - d. The target is Military.
73. Your Outer Defensive Perimeter is located at:
- a. 64 nm
 - b. 128 nm
 - c. 256 nm
 - d. 512 nm
74. If you've just noticed three targets near your inner perimeter, which of the following should you do next?
- a. Engage the target nearest the inner perimeter.
 - b. Engage the fastest target near the inner perimeter.
 - c. Zoom-Out to check the outer perimeter.
 - d. Zoom-In to check how close targets are to the inner perimeter.
75. If you Zoom-Out to find three targets clustered around your Outer Perimeter, how would you determine which target is the marker target?
- a. Check to see which target is closest to the outer perimeter.
 - b. Check the speeds of the targets
 - c. Check to see which target is Civilian
 - d. Check to see which target is Hostile
76. What is the purpose of marker targets?
- a. To determine which Targets are Hostile and which are Peaceful.
 - b. To locate your Inner Defensive Perimeter.
 - c. To quickly determine the speeds of targets near your perimeters.
 - d. To locate your Outer Defensive Perimeter.

77. Which of the following pieces of information is NOT useful for prioritizing targets?

- a. The distance of targets from the outer defensive perimeter.
- b. Whether the target is peaceful or hostile.
- c. The distance of targets from the inner defensive perimeter.
- d. The speed of targets near your inner and outer defensive perimeters.

78. Which of the following functions is most useful for identifying marker targets?

- a. Zoom-in
- b. Right-button feedback.
- c. Engage Shoot or Clear
- d. Zoom-out

79. If three Targets are about 10 miles outside your outer defensive perimeter, which of the following should you do to prioritize the Targets?

- a. Engage the fastest Target
- b. Engage the hostile Target
- c. Engage the closest Target
- d. It makes no difference in what order you engage the Targets.

80. On the average, approximately how many Targets pop-up during each practice trial?

- a. 1
- b. 3
- c. 6
- d. 9

81. Which of the following would be the most effective strategy for defending your outer defensive perimeter?

- a. Zoom-out to 128 nm, locate the Marker Targets, and check the speed of targets near the outer perimeter.
- b. Zoom-out to 256 nm, locate the Marker Targets, and check the speed of targets near the outer perimeter.
- c. Zoom-out to 128 nm, locate a Hostile Air Target, and check the speed of targets near that target.
- d. Zoom-out to 256 nm, locate a Hostile Air Target, and check the speed of targets near that target.

82. If all penalty intrusions cost -100 points, which would be the most effective strategy?

- a. Do not allow any Targets to enter your Inner Defensive perimeter, even if it means allowing targets to cross your Outer Defensive perimeter.
- b. Do not allow any Targets to enter your Outer Defensive perimeter, even if it means allowing targets to cross your Inner Defensive perimeter.
- c. Defend both your Inner and Outer Defensive perimeters equally.
- d. None of these are effective strategies.

83. It is important to make trade-offs between targets:

- a. That are Hostile and those that are Peaceful.
- b. Approaching your Inner and Outer perimeters.
- c. That are Civilian and those that are Military.
- d. That have already crossed your Inner Defensive perimeter, and those that are approaching your Outer Defensive perimeter.

APPENDIX P

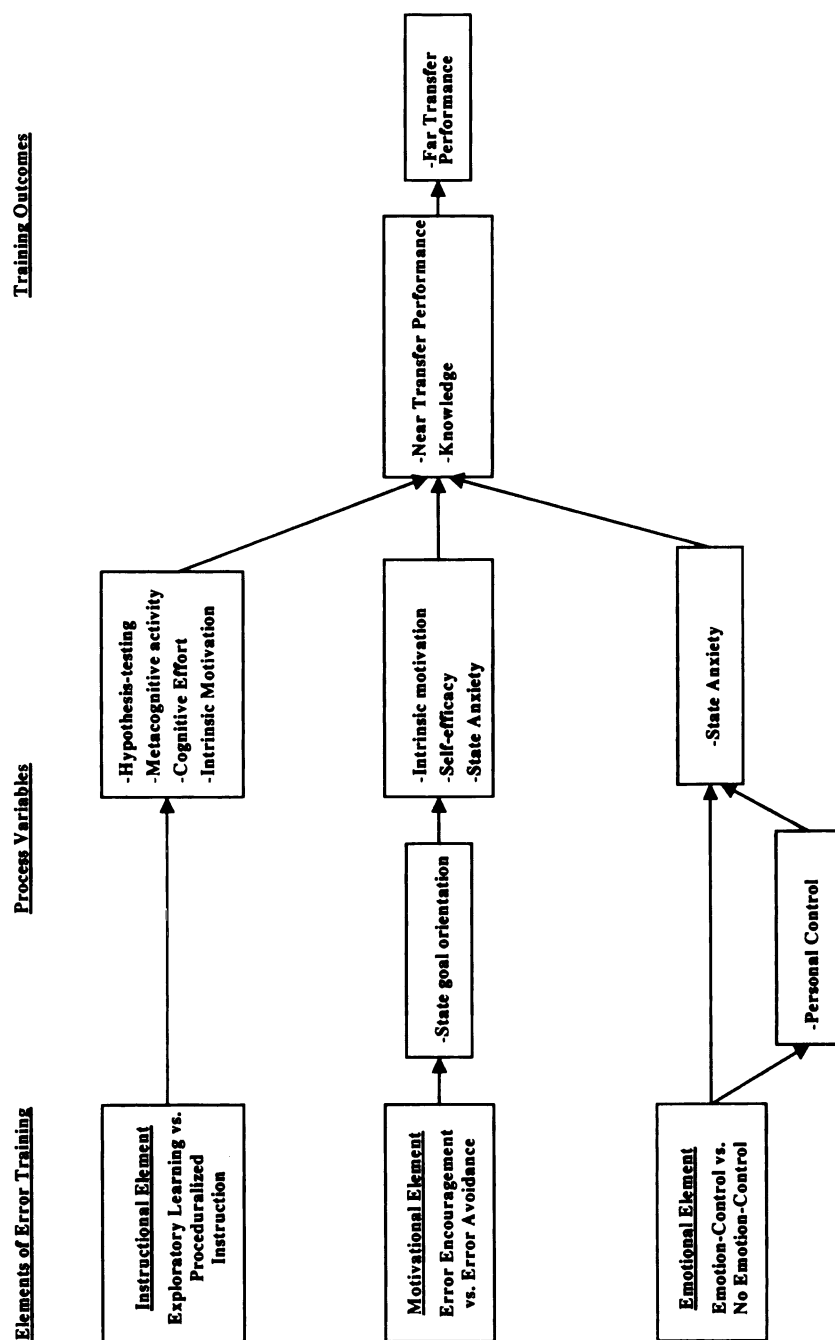


Figure 1. Conceptual model of the impact of the instructional, motivational, and emotional elements of error training on training performance, knowledge, and generalization performance.

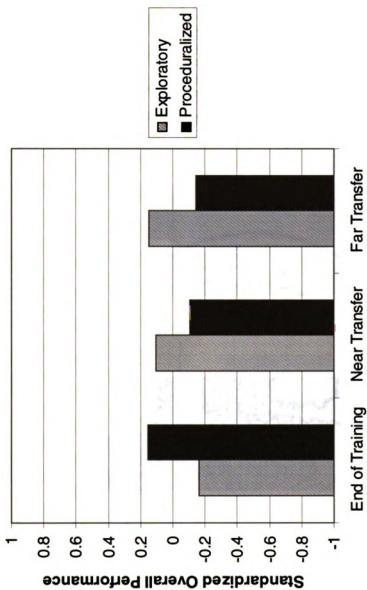


Figure 2. Mean standardized overall performance for exploratory and proceduralized instruction conditions at the end of training, in near transfer, and in far transfer. Differences at end of training and in far transfer are significant.

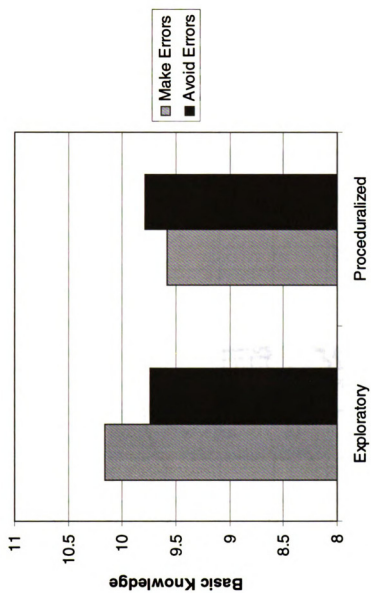


Figure 3. Interaction between instructional and motivational elements on basic knowledge at the end of training.

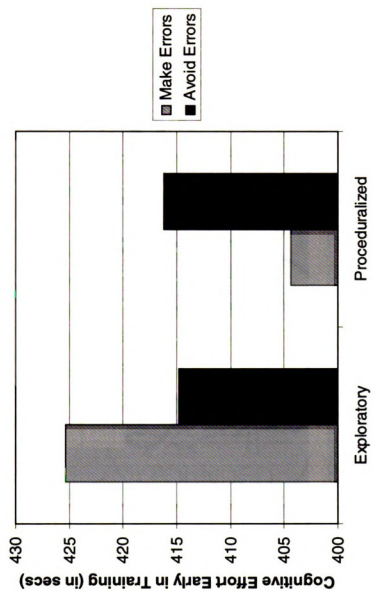


Figure 4. Significant interaction between instructional and motivational elements on cognitive effort early in training.

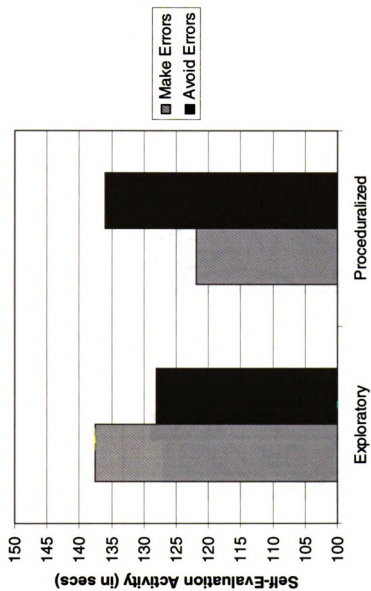


Figure 5. Interaction between instructional and motivational elements on self-evaluation activity.

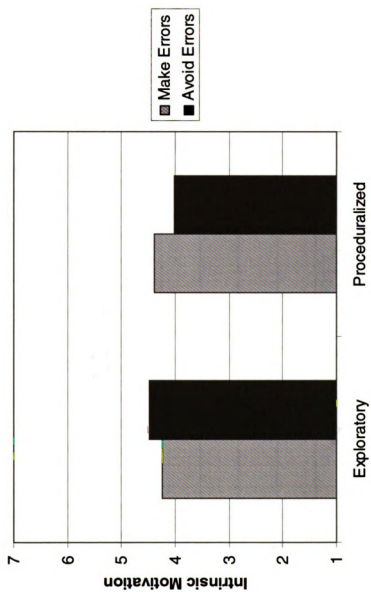


Figure 6. Interaction between instructional and motivational elements on intrinsic motivation.

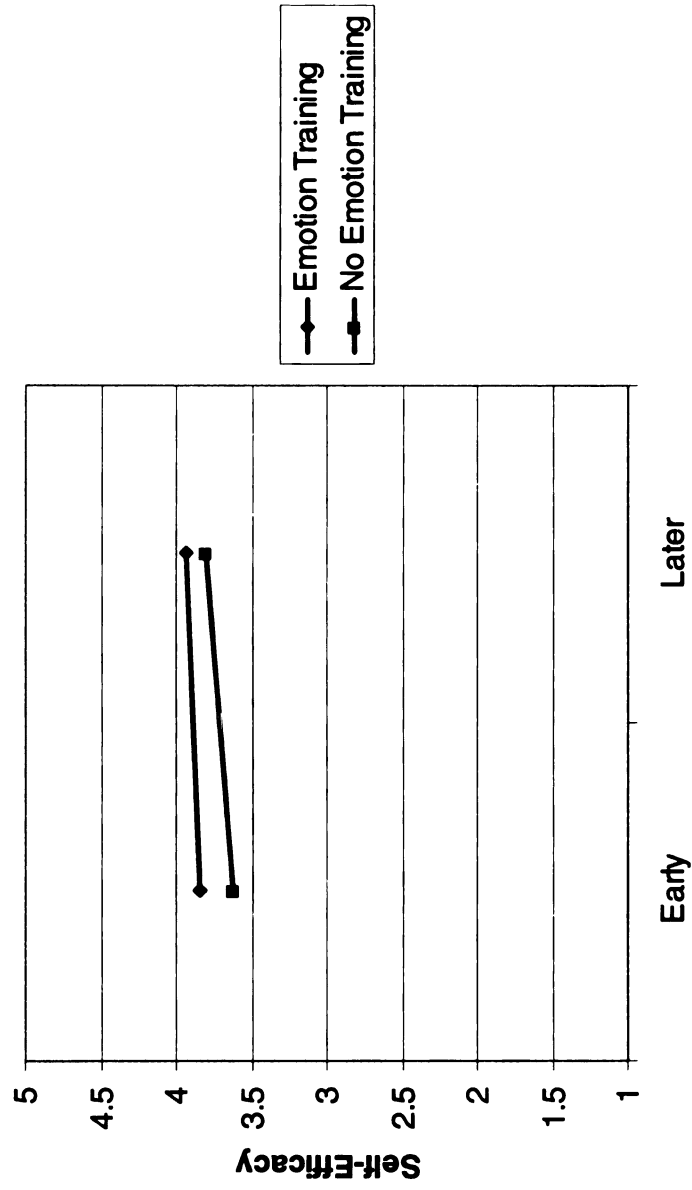


Figure 7. Effect of emotion-control training on self-efficacy early and later in training.

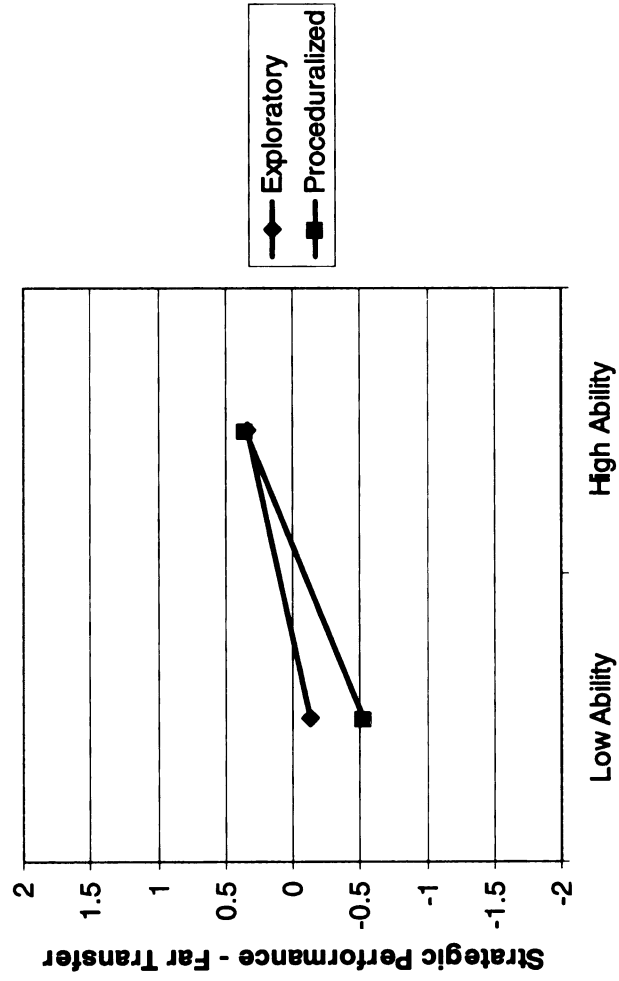


Figure 8. Interaction between instructional element and cognitive ability on strategic performance in the far transfer trial.

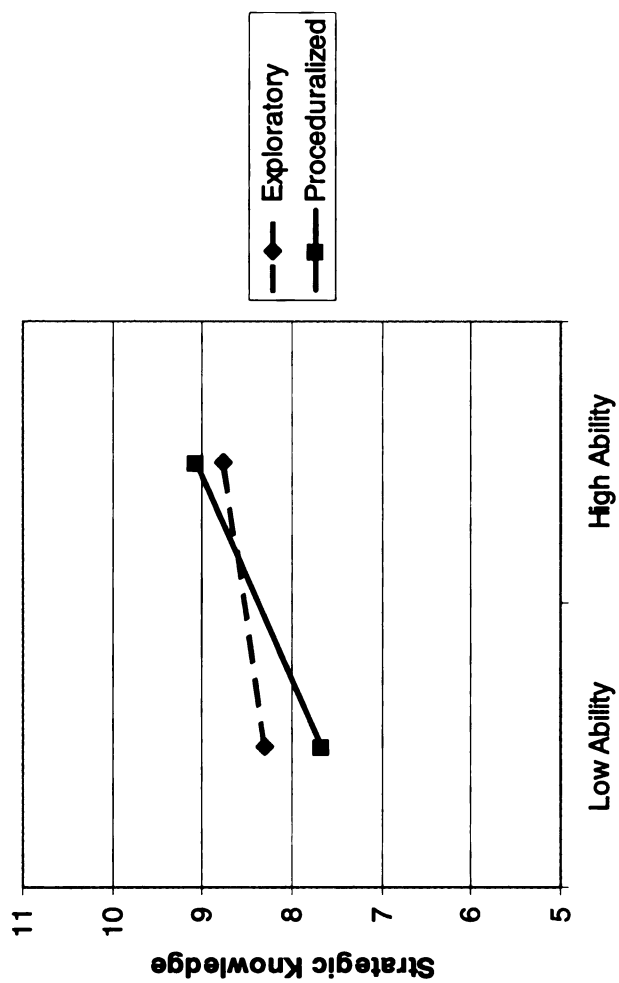


Figure 9. Interaction between instructional element and cognitive ability on strategic knowledge at the end of training.

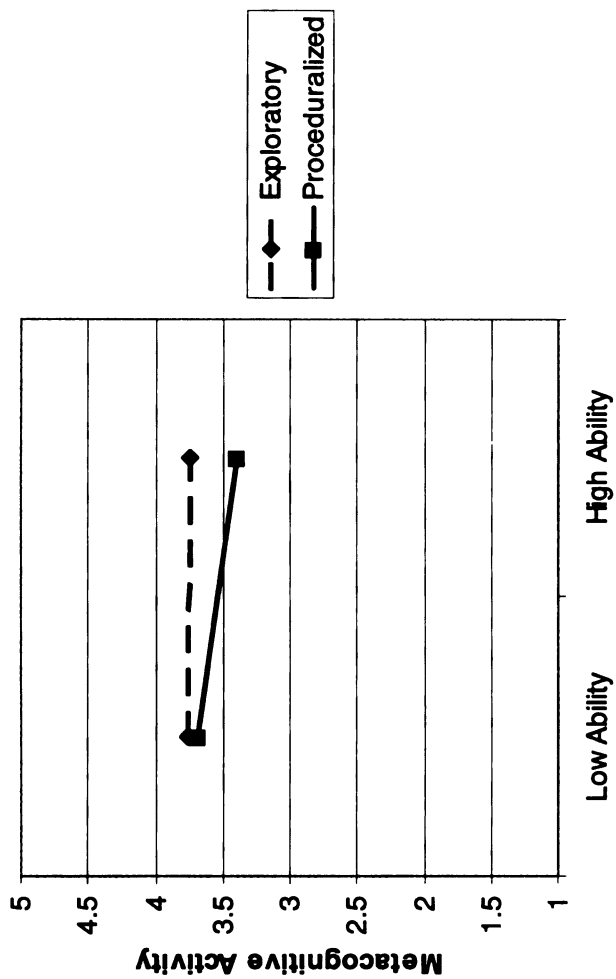


Figure 10. Interaction between instructional element and cognitive ability on metacognitive activity at the end of training.

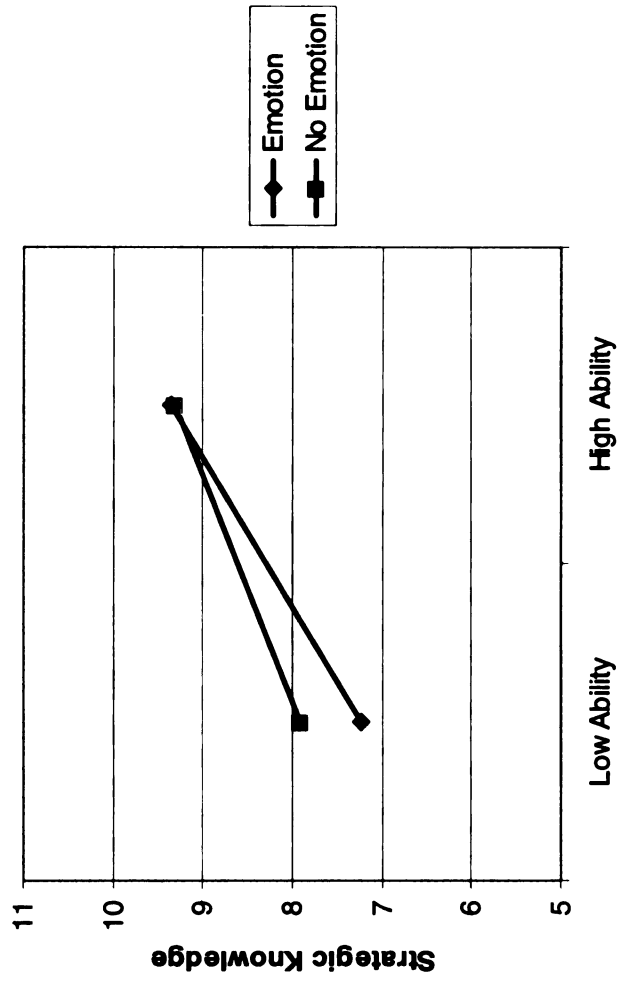


Figure 11. Interaction between emotional element and cognitive ability on strategic knowledge at the end of training.

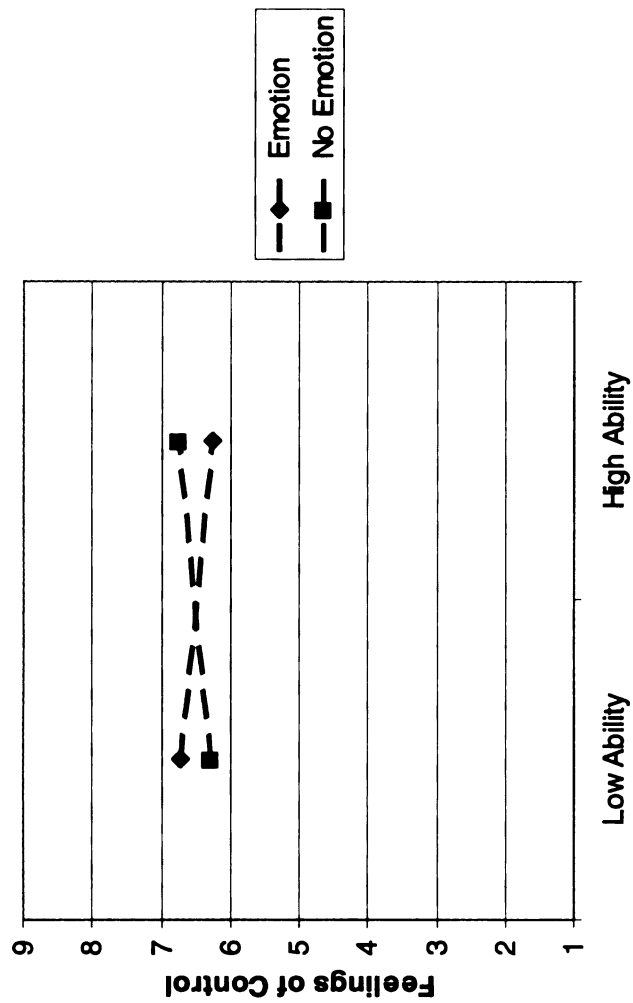


Figure 12. Interaction between emotional element and cognitive ability on feelings of control at the end of training.

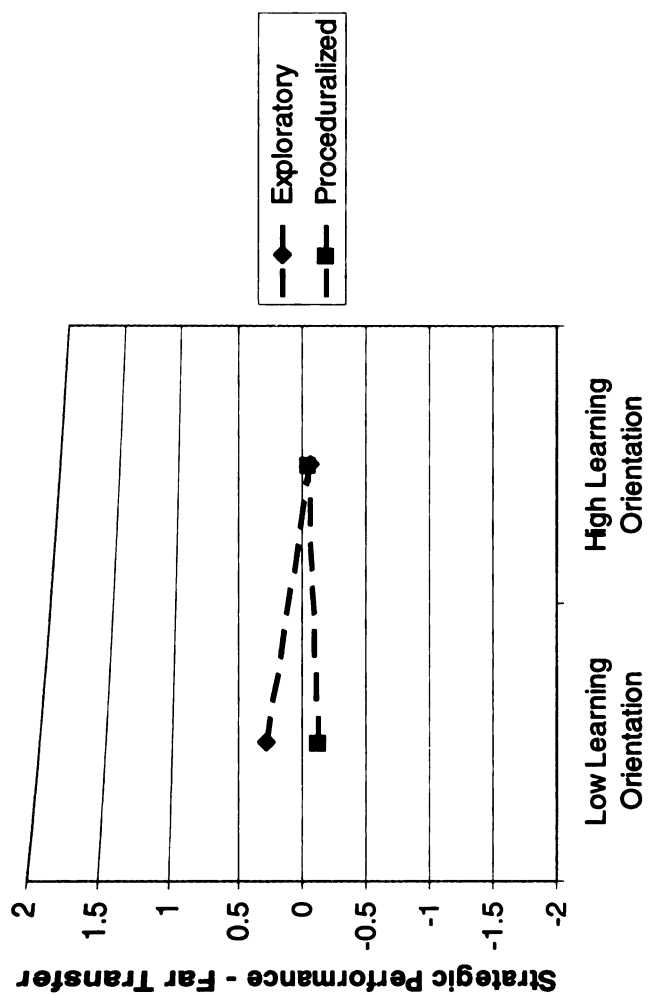


Figure 13. Interaction between instructional element and learning orientation on strategic performance in the far transfer trial.

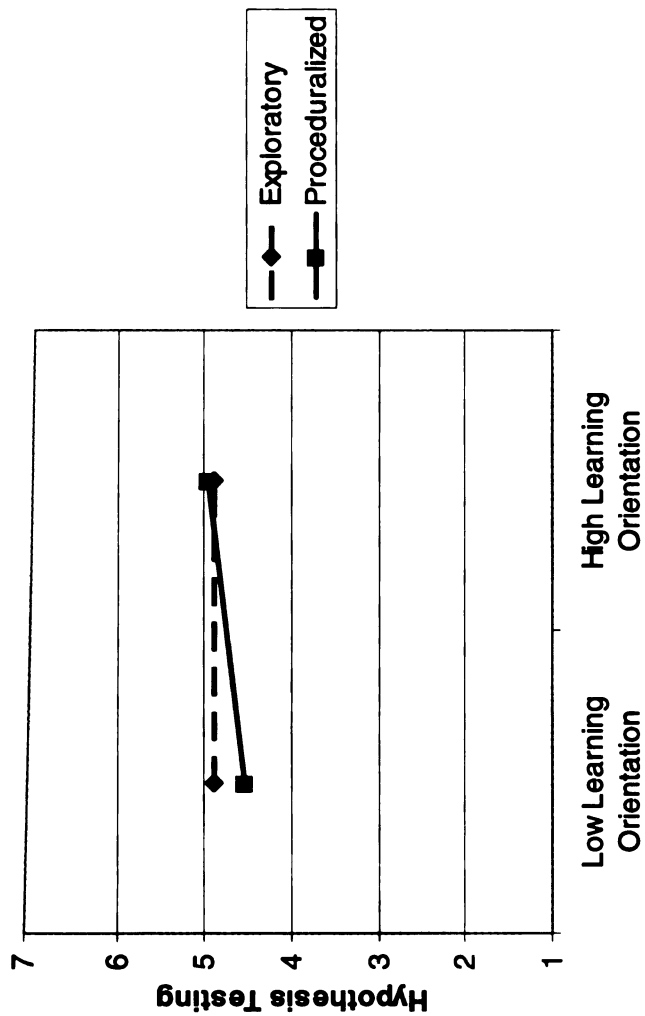


Figure 14. Interaction between instructional element and learning orientation on hypothesis testing at the end of training.

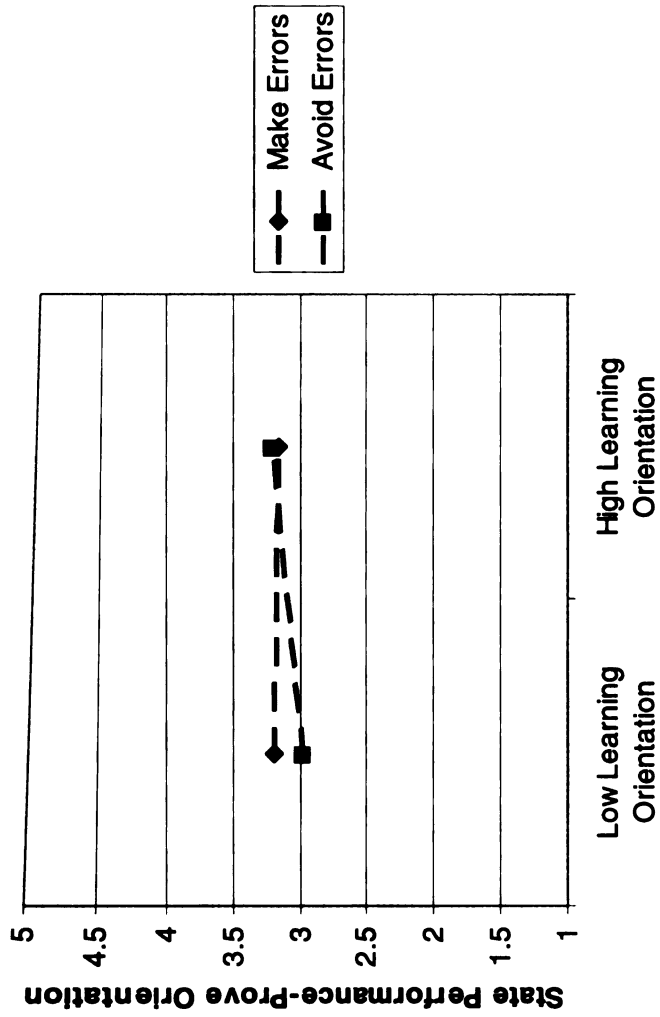


Figure 15. Interaction between motivational element and learning orientation on state performance-prove orientation at the end of training.

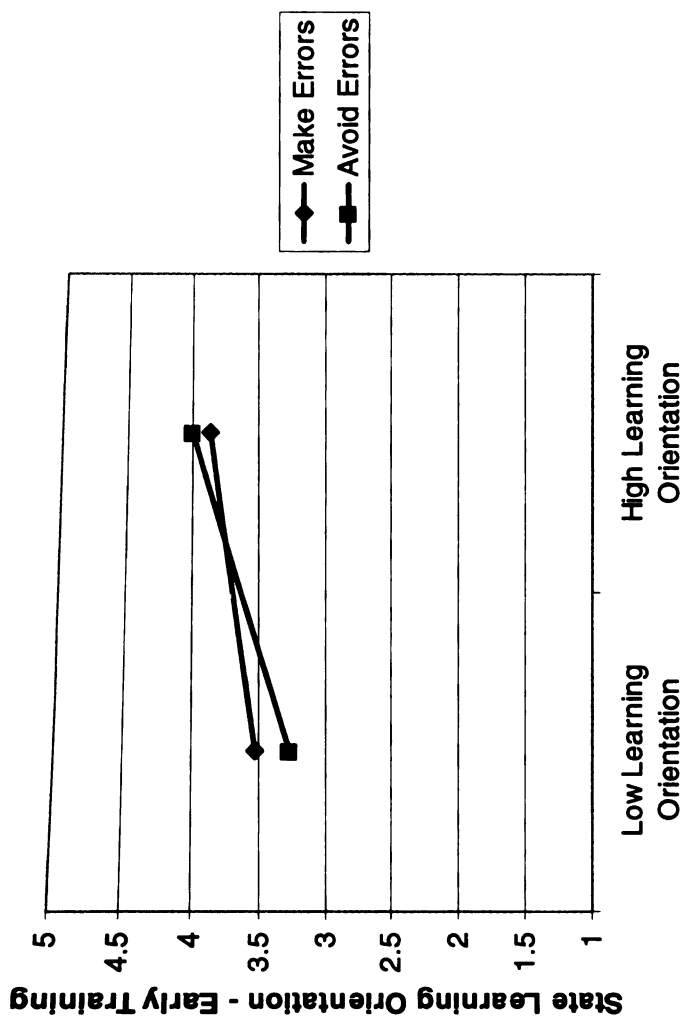


Figure 16. Interaction between motivational element and learning orientation on state learning orientation in the beginning of training.

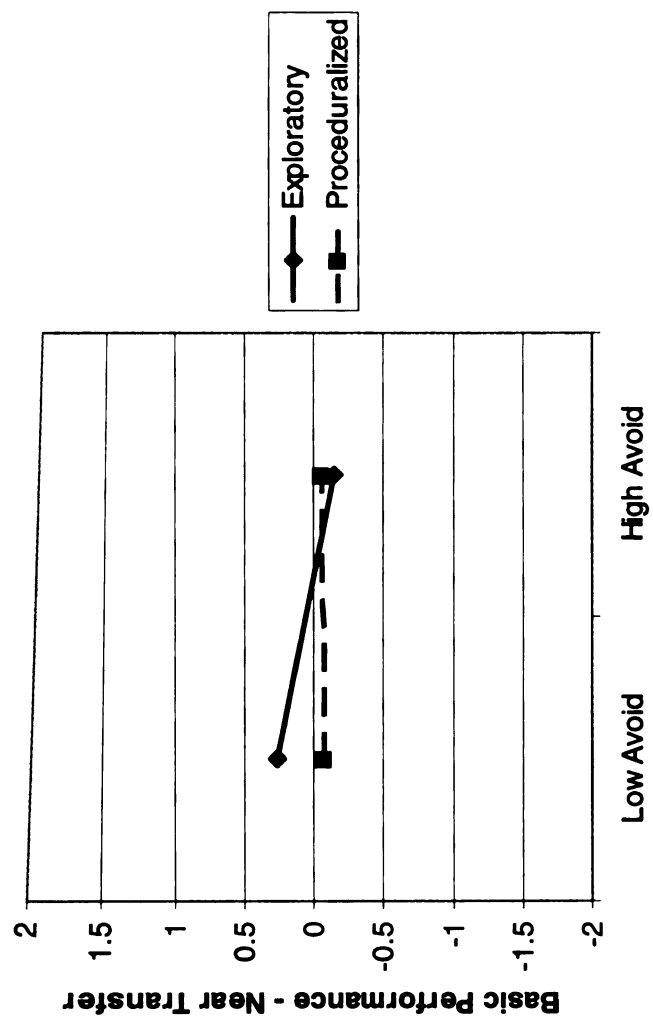


Figure 17. Interaction between instructional element and performance-avoid orientation on basic performance during near transfer.

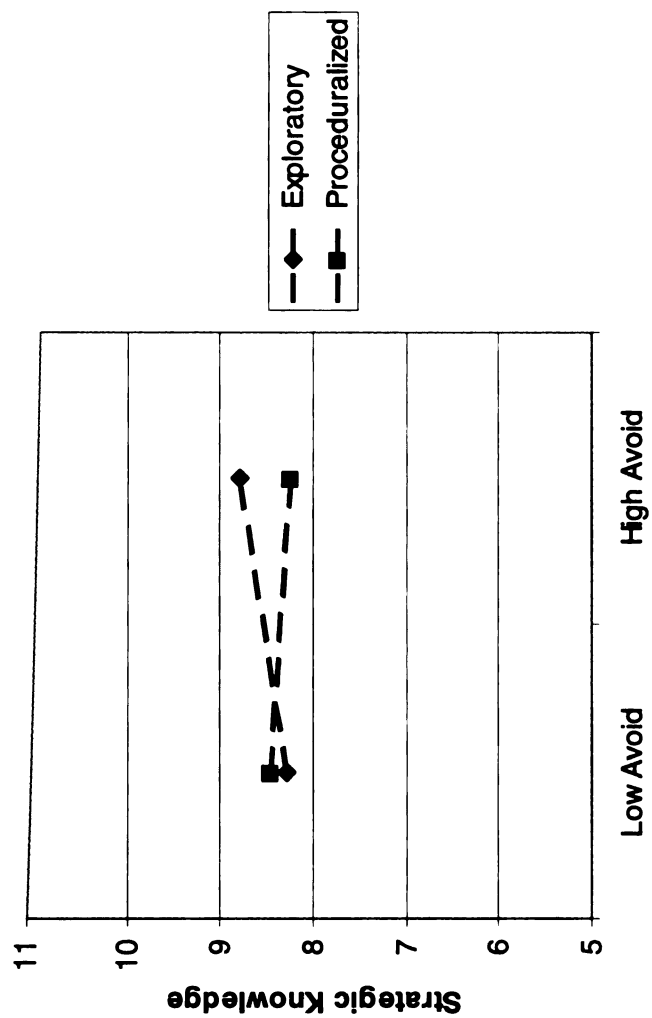


Figure 18. Interaction between instructional element and performance-avoid orientation on strategic knowledge at the end of training.

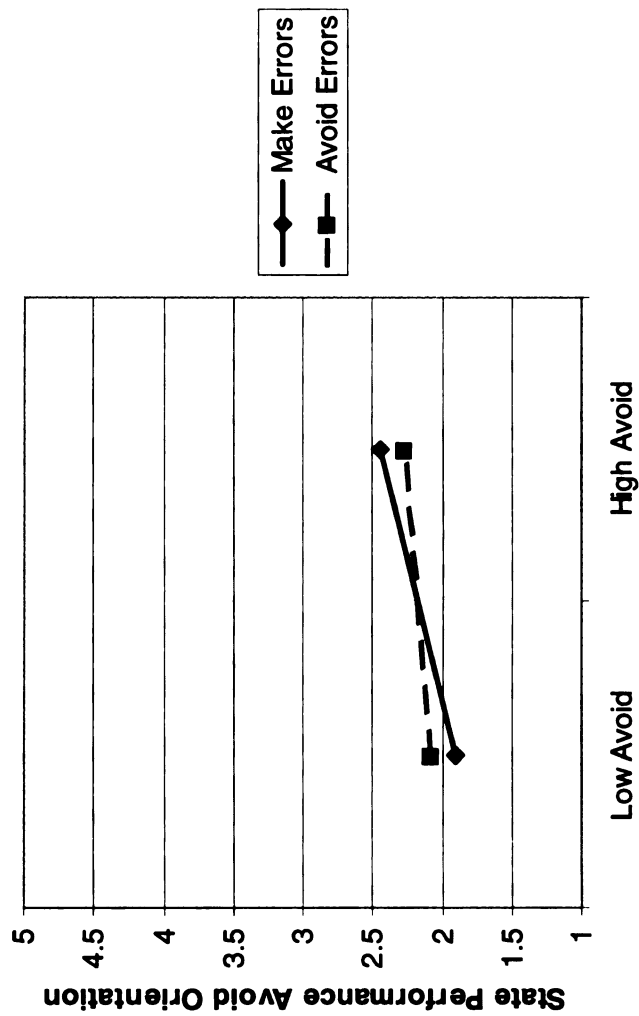


Figure 19. Interaction between motivational element and performance-avoid orientation on state performance-avoid orientation at the end of training.

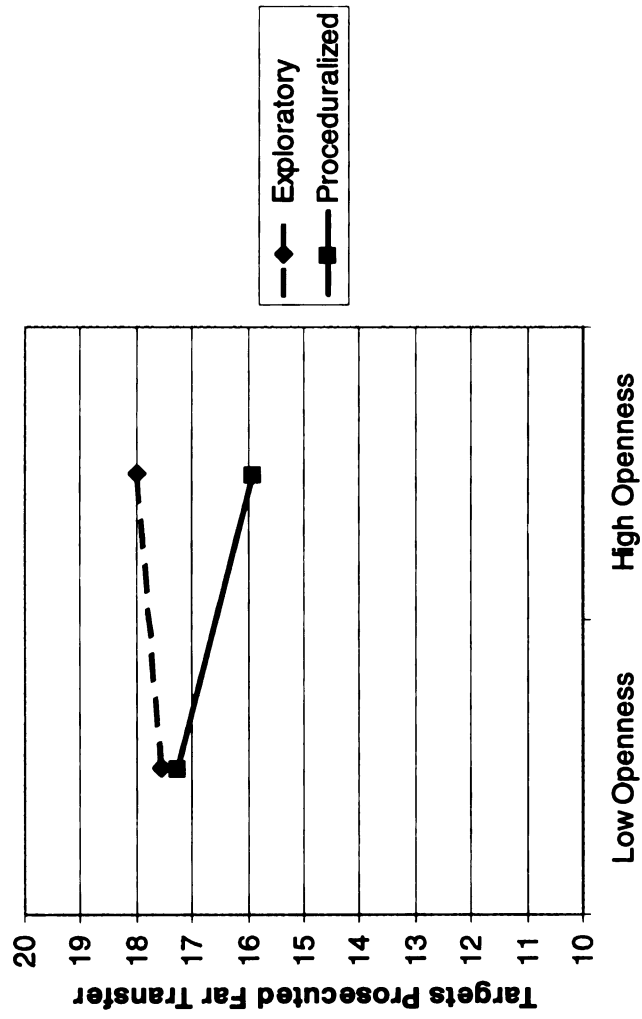


Figure 20. Interaction between instructional element and openness to experience on number of targets prosecuted in far transfer trial.

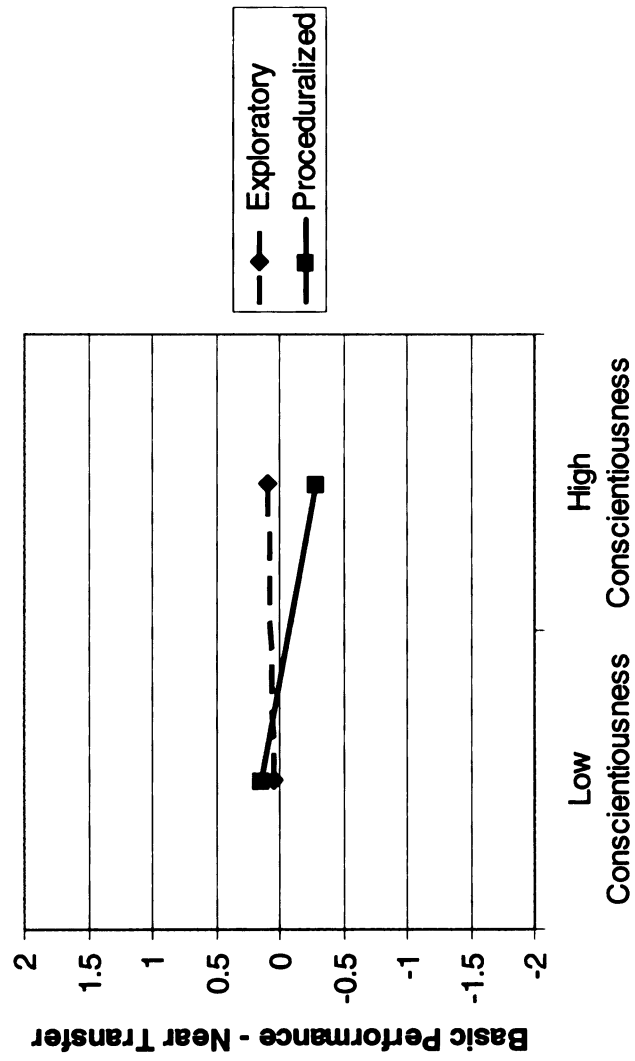


Figure 21. Interaction between instructional element and conscientiousness on basic performance in near transfer.

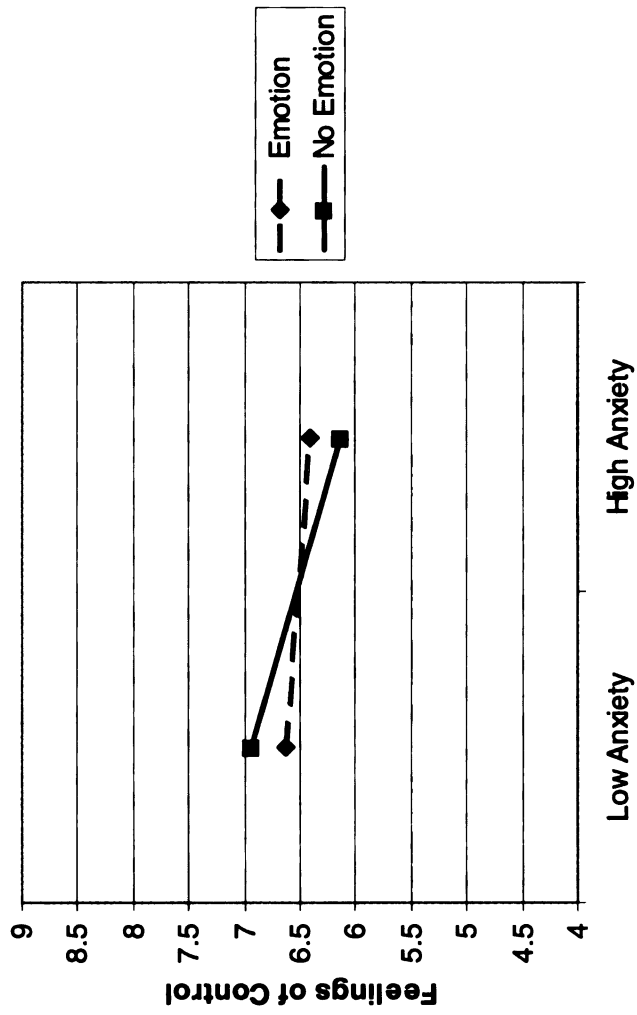


Figure 22. Interaction between emotional element and trait anxiety on feelings of personal control.

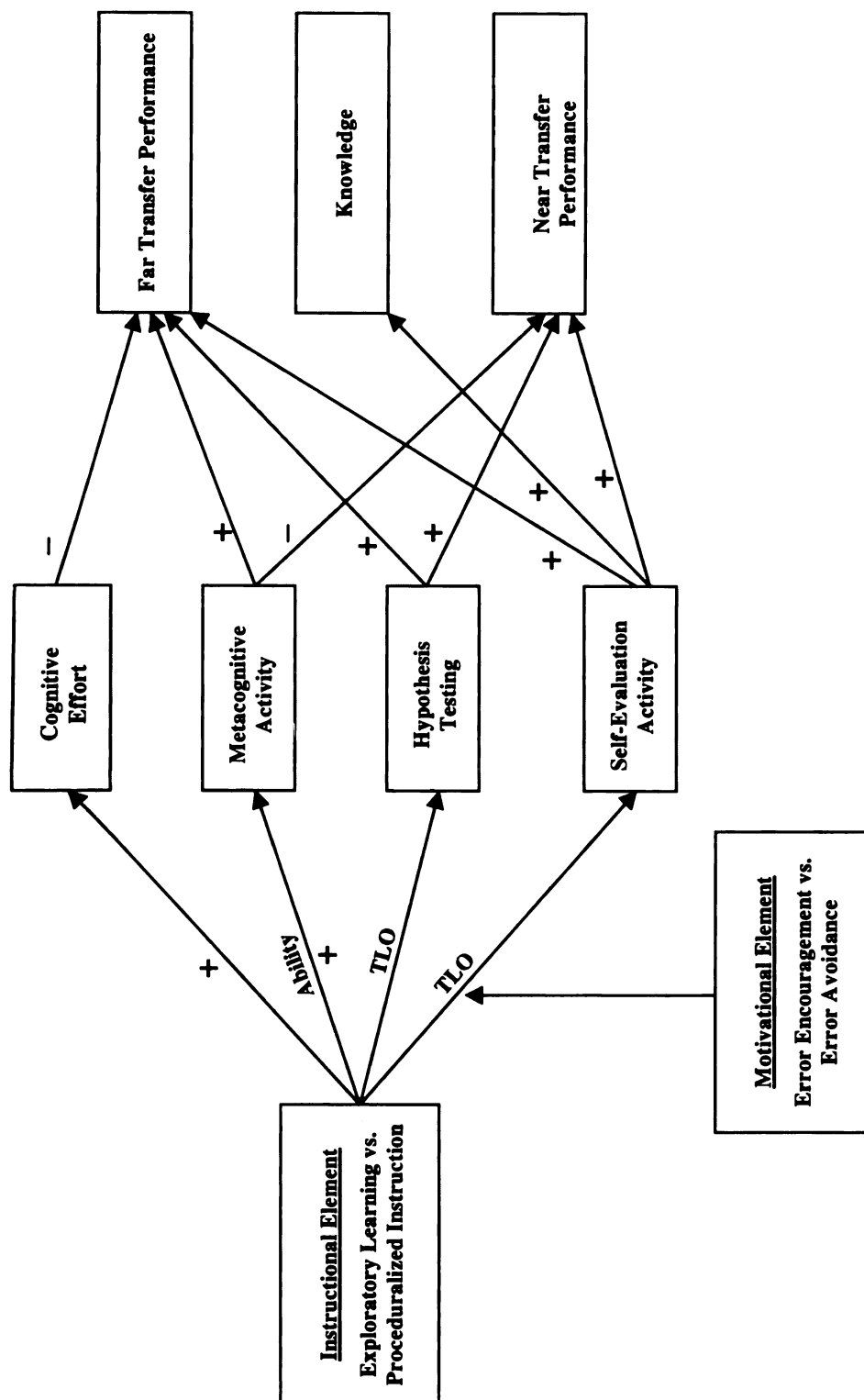


Figure 23. Heuristic summarizing findings for instructional element. Note: TLO is trait learning orientation.

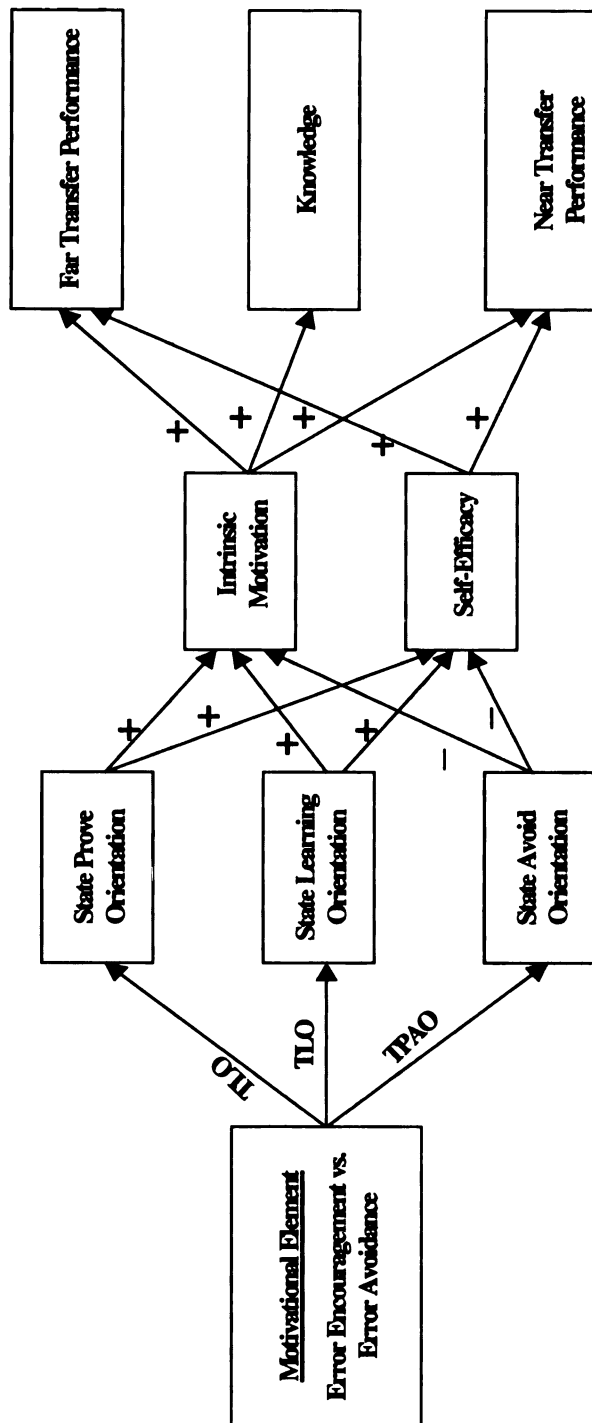


Figure 24. Heuristic summarizing findings for motivational element. TLO is trait learning orientation and TPAO is trait performance-avoid orientation.

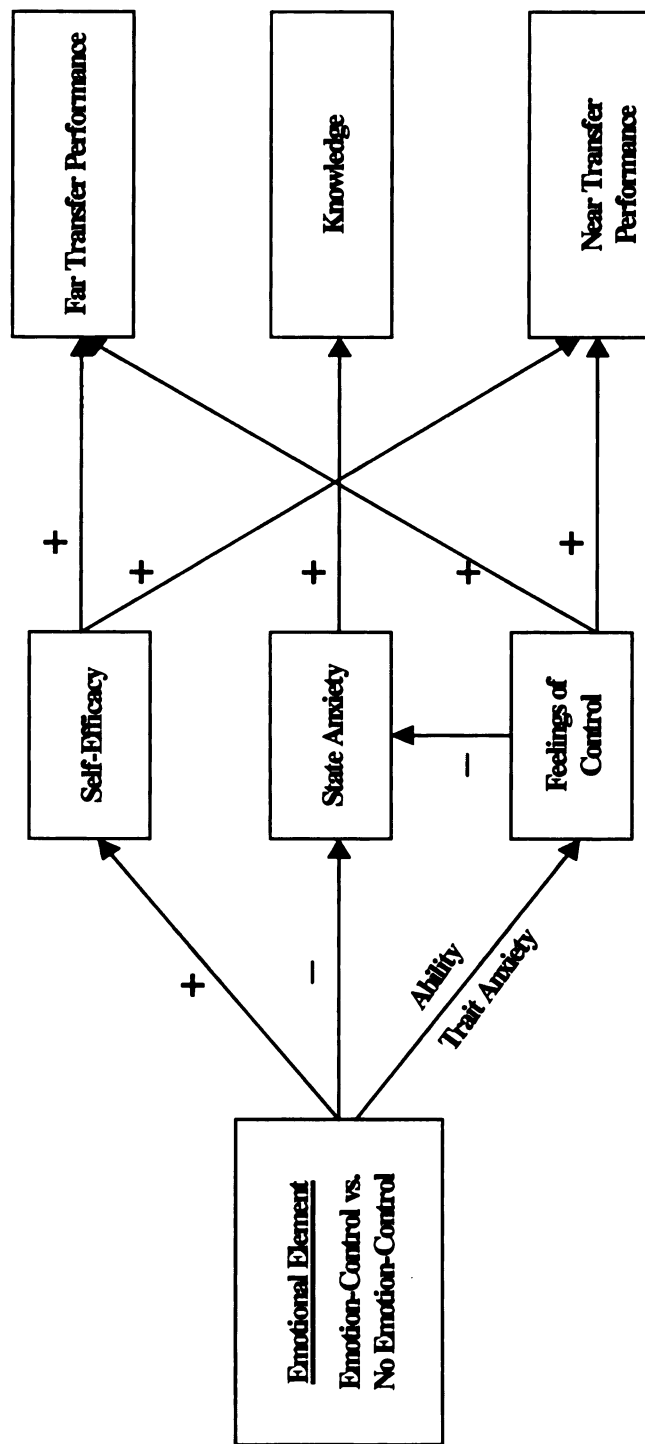


Figure 25. Heuristic summarizing findings for emotional element.

APPENDIX Q

Table 1. Summary of Study Hypotheses and Results

Hypothesis	Independent Variables	Dependent Variables	Results
1	Instructional element	Near Transfer Performance	Partially supported - The instructional element did not significantly impact basic or strategic performance in near transfer.
2	Instructional element	Knowledge	Rejected - The instructional element did not have a significant effect on trainees' basic or strategic knowledge.
3	Instructional element	Far Transfer Performance	Supported - Exploratory learning led to higher levels of both basic and strategic performance in the far transfer trials than proceduralized instruction.
4a	Instructional element	Hypothesis-testing	Rejected - The instructional element did not have a significant direct effect on trainees' hypothesis-testing activities.
4b	Hypothesis-testing	Knowledge and performance	Partially supported - Hypothesis-testing had a significant and positive effect on trainees' strategic performance during near and far transfer.
5a	Instructional element	Metacognitive Activity	Supported - Exploratory learning led to more metacognitive activity than proceduralized instruction.

5b	Metacognitive activity	Knowledge and performance	Partially supported - Metacognitive activity had a positive relationship with trainees' basic performance in far transfer, but a negative relationship with their strategic performance during near transfer. ----- - Self-evaluation activity was positively related to all the strategic outcomes.
6a	Instructional element	Cognitive effort	Supported - Exploratory learning led to more cognitive effort than proceduralized instruction. ----- - Early in training, significant interaction emerged for instruction x motivation. Individuals who received exploratory instruction and error encouragement displayed highest levels of cognitive effort.
6b	Cognitive effort	Knowledge and performance	Rejected - Cognitive effort led to lower levels of basic performance in near transfer and strategic performance during far transfer.
7a	Instructional element	Intrinsic Motivation	Rejected - The instructional element did not have a significant effect on intrinsic motivation. ----- - The instructional and motivational elements interacted to significantly influence intrinsic motivation. The group that received proceduralized instruction and error avoidance directions had the lowest level of intrinsic motivation; the other three groups displayed similar levels of intrinsic motivation.

7b	Intrinsic Motivation	Knowledge and performance	Supported - Intrinsic motivation displayed a positive relationship with all the outcomes except near transfer basic performance.
8	Motivational element	Near Transfer Performance	Partially supported - Error encouragement led to higher levels of strategic performance in near transfer than error avoidance, but there was no effect for basic performance.
9	Motivational element	Knowledge	Rejected - The motivational element did not have a significant direct effect on basic or strategic knowledge. ----- - There was a significant interaction between the motivational and instructional elements on basic knowledge. Error encouragement led to higher levels of basic knowledge when paired with exploratory instruction.
10	Motivational element	Far Transfer Performance	Supported - Error encouragement led to higher levels of basic and strategic performance in the generalization trial than error avoidance.

11	Motivational element	State goal orientation	Rejected - The motivational element did not have a direct effect on trainees' learning, performance-prove, or performance-avoid state goal orientation. - Motivational element interacted with trait goal orientation to influence individuals' state goal orientation. • Error encouragement increased state learning orientation and performance-prove orientation for individuals low in learning orientation. • Error encouragement reduced state performance-avoid orientation for individuals low in trait avoid orientation. • Error instructions did not interact with trait performance-prove orientation.
12	State goal orientation	Intrinsic Motivation	Supported - Learning orientation and performance-prove orientation had a positive relationship with intrinsic motivation and performance-avoid orientation had a negative relationship with intrinsic motivation.
13a	State goal orientation	Self-efficacy	Supported - Learning orientation and performance-prove orientation had a positive relationship with self-efficacy and performance-avoid orientation had a negative relationship with self-efficacy.

13b	Self-efficacy	Performance	Partially supported - Self-efficacy was positively related to trainees' basic performance in near and far transfer and strategic performance in far transfer.
14a	State goal orientation	State anxiety	Partially supported - State anxiety was positively and significantly related to performance-avoid orientation but not significantly related to learning or performance-prove orientation.
14b	State Anxiety	Knowledge and performance	Rejected - State anxiety did not display a significant relationship with most of the outcomes. It had a positive relationship with strategic knowledge.
15	Emotional element	Near Transfer Performance	Rejected - Emotion-control training did not have a significant effect on trainees' basic performance in near transfer and led to lower levels of strategic performance in near transfer.
16	Emotional element	Knowledge	Rejected - Emotion-control training did not have a significant effect on trainees' knowledge at the end of training and led to lower levels of knowledge early in training.
17	Emotional element	Far Transfer Performance	Rejected - Emotion-control training did not have an effect on individuals' basic or strategic performance in the generalization trial.

18	Emotional element	State Anxiety	Supported - Emotion-control training led to lower levels of state anxiety. This reduction was greatest early in training.
19a	Emotional element	Feelings of control	Rejected - Emotion-control training did not have a significant direct effect on trainees' feelings of personal control.
19b	Feelings of control	State anxiety	Supported - Feelings of control displayed a negative relationship with trainees' state anxiety. ----- - Feelings of control had a positive, direct relationship with trainees' basic performance in the near and far transfer trials.
20	Instructional element x motivational element	Knowledge and performance	Partially supported - The instructional and motivational elements interacted to significantly influence basic knowledge.
21	Instructional element x emotional element	Knowledge and performance	Rejected - The instructional and emotional elements did not interact to significantly impact trainees' knowledge or performance.
22	Motivational element x emotional element	Knowledge and performance	Rejected - The motivational and emotional element did not interact to significantly impact trainees' knowledge or performance.

23	Instructional element x cognitive ability	Knowledge and performance	Partially supported - The instructional element and cognitive ability interacted to significantly influence trainees' strategic performance in generalization and strategic knowledge. High ability individuals where relatively unaffected by the nature of the instruction, whereas low ability individuals had higher levels of knowledge and performance when given exploratory instruction. - There was also a significant interaction on metacognitive activity. High ability individuals had lower levels of metacognitive activity when given proceduralized instruction.
24	Instructional element x openness	Knowledge and performance	Partially supported - Individuals low in openness displayed similar levels of performance efficiency when given exploratory and proceduralized instruction. Individuals high in openness displayed higher levels of performance efficiency when given exploratory instruction.
25	Motivational element x conscientiousness	Knowledge and performance	Rejected - The motivational element did not interact with conscientiousness to influence trainees' knowledge or performance - Follow-up analyses showed that the instructional element interacted with conscientiousness to influence individuals' overall and basic performance in near transfer. Trainees' high in conscientiousness performed better when given exploratory instruction.

26	Emotional element x cognitive ability	Knowledge and performance	Partially supported - The emotional element and cognitive ability interacted to significantly influence trainees' strategic knowledge. Trainees high in ability were unaffected by the emotion-control training, whereas those low in ability had higher levels of knowledge when they were not given the emotion-control training. - There was also a significant interaction on feelings of control. Individuals low in ability felt more in control when given the emotion-control training, whereas individuals high in ability felt more in control when not given the emotion-control training.
27	Emotional element x Trait Anxiety	Knowledge and performance	Rejected - The emotional element did not interact with trait anxiety to significantly influence individuals knowledge or performance - There was a meaningful interaction between the emotion-control training and trait anxiety on trainees' feelings of control. The emotion-control training prevented the negative effect of trait anxiety on individuals' feelings of control.

Table 2. Errors in TANDEM

Level of Regulation	Error	Cause of Error	Source of Error Detection	Type of Performance Impacted by Error
Knowledge-based	Incorrect target decision-making sequence	Incomplete or inaccurate knowledge of proper target decision-making sequence.	Forcing function (final decision cannot be made unless sub-decisions are made in appropriate order)	Basic – prevents target prosecution and limits score potential
	Failure to use or infrequent use of zoom function	Incomplete or inaccurate knowledge of how to use the zoom function and/or the importance of zooming.	Post-trial feedback	Basic – prevents target separation and proper target selection Strategic – prevents monitoring of outer perimeter and awareness of task situation
	Failure to prosecute pop-up targets	Incomplete or inaccurate knowledge of pop-up targets and their importance; lack of awareness of overall task environment	Environmental Cue (visual awareness of targets crossing perimeter); Post-trial feedback	Strategic – increases the number of perimeter intrusions.
	Failure to hook marker targets	Incomplete or inaccurate knowledge of marker targets and their importance	Environmental Cue (visual awareness of targets crossing perimeters); Post-trial feedback	Strategic – prevents identification of outer perimeter and thus increases intrusions
	Failure to prosecute high priority targets	Incomplete or inaccurate knowledge of how to prioritize targets	Environmental Cue (visual awareness of targets crossing perimeter); Post-trial feedback	Strategic – increases the number of perimeter intrusions

Table 2 (cont.). Errors in TANDEM

Rule-based	Using a strategy to prevent perimeter intrusions that worked in the past but is inappropriate given current conditions	Not noticing changes in task environment (e.g, distribution of targets, characteristics of specific targets, rule properties)	Environmental Cue (visual awareness of targets crossing perimeters); Immediate and post-trial feedback	Strategic – greater number of perimeter intrusions (Note: particularly relevant in generalization when task characteristics are altered dramatically).
Skill-based	Hooking unintended target	Working too fast; lack of on-task attention; not enough target separation	Environmental Cue (unintended target is highlighted)	Basic – time is wasted changing targets, which reduces targets prosecuted
	Selecting unintended menu option during target classification	Working too fast; lack of on-task attention	Environmental Cue (unintended option is highlighted); Immediate and post-trial decision feedback	Basic – incorrect decisions cost points and lead to lower scores
	Selecting unintended final engagement option	Working too fast; lack of on-task attention	Environmental Cue (unintended option is highlighted); Immediate and post-trial decision feedback	Basic – incorrect decisions cost points and lead to lower scores

Table 3

Summary of Variables Included in Hierarchical Regression Analyses

Dependent Variable Set	Independent Variable Set
▪ Knowledge & Performance • Basic Knowledge • Strategic Knowledge • Overall Performance • Basic Performance • Strategic Performance	▪ Individual Differences • Cognitive Ability • Trait Goal Orientation • Conscientiousness • Openness to Experience • Trait Anxiety ▪ Error Training Elements • Instructional Element • Motivational Element • Emotional Element • Instructional x Motivational
▪ Instructional Processes • Hypothesis-Testing • Metacognitive Activity • Self-Evaluation Activity • Cognitive Effort	▪ Individual Differences • Cognitive Ability • Trait Goal Orientation • Conscientiousness • Openness to Experience ▪ Error Training Elements • Instructional Element • Motivational Element • Instructional x Motivational
▪ Motivational Processes • Intrinsic Motivation • State Goal Orientation • Self-efficacy	▪ Individual Differences • Cognitive Ability • Trait Goal Orientation • Conscientiousness • Trait Anxiety ▪ Error Training Elements • Instructional Element • Motivational Element • Instructional x Motivational
▪ Emotional Processes • State Anxiety • Feelings of control	▪ Individual Differences • Cognitive Ability • Trait Goal Orientation • Trait Anxiety ▪ Error Training Elements • Emotional Element

Table 4

Means, Standard Deviations, and Intercorrelations for Variables Included in Analyses

Variable	M	SD	1	2	3	4	5	6	7	8	9	10
1. Instructional element	0.49	0.50	--									
2. Motivational element	0.51	0.50	-.01	--								
3. Emotion-control element	0.50	0.50	.03	-.01	--							
4. Cognitive Ability	0.60	0.70	.06	.05	-.10	--						
5. Trait learning orientation	4.61	0.78	.06	-.02	.11*	.14*	--					
6. Trait performance-prove orientation	4.15	1.04	.16**	-.04	.00	.08	.18**	--				
7. Trait performance-avoid orientation	3.23	0.99	.02	.04	-.01	-.13*	-.29**	.39**	--			
8. Conscientiousness	5.01	0.84	.05	.04	.02	-.17**	.23**	.06	-.10	--		
9. Openness to experience	4.88	0.80	.00	.02	-.04	.24**	.34**	-.05	-.24**	-.15**	--	
10. Trait Anxiety	1.94	0.49	.13*	.05	-.01	-.07	-.19**	.21**	.35**	-.31**	-.04	--
11. Hypothesis-testing (1)	4.66	1.12	-.08	.09	-.03	-.02	.08	.01	-.04	.08	.12**	-.11**
12. Hypothesis-testing (2)	4.82	1.10	.07	.02	.01	-.01	.22**	.05	-.09	.18**	.19**	-.18**
13. Metacognitive activity (1)	3.72	0.63	.04	.00	.02	-.03	.26**	.04	-.12*	.18**	.15**	-.06
14. Metacognitive activity (2)	3.65	0.73	.16**	.03	.04	-.06	.24**	.06	-.09	.16**	.17**	-.06
15. Cognitive effort (1)	415.07	40.48	.12*	-.01	-.05	.07	.00	.14**	.00	.01	.08	.06

Note: (1) denotes that the variable was measured early in training; (2) denotes the variable was measured at the end of training.

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

Table 4 (cont.)

Means, Standard Deviations, and Intercorrelations for Variables Included in Analyses

Variable	M	SD	1	2	3	4	5	6	7	8	9	10
16. Cognitive effort (2)	249.41	157.91	.47**	-.01	.05	-.10	.05	.14**	.12*	.05	.06	.11*
17. Self-evaluation activity (1)	204.33	42.48	.07	.05	.02	-.01	.13*	-.06	-.02	-.05	.12	.06
18. Self-evaluation activity (2)	130.82	45.40	.04	-.03	-.09	.07	.03	.00	-.03	.04	.04	-.03
19. Intrinsic motivation (1)	4.60	1.26	.03	.05	.05	.07	.09	-.08	-.08	.06	.08	-.06
20. Intrinsic motivation (2)	4.28	1.34	.06	.03	-.01	.03	.15**	-.02	-.10	.13*	.10	-.11
21. State learning orientation (1)	3.67	0.82	-.05	.02	.10	-.04	.33**	-.09	-.24**	.13*	.17**	-.09
22. State learning orientation (2)	3.68	0.82	-.04	.06	.11*	-.03	.35**	-.04	-.22**	.24**	.14**	-.13*
23. State prove orientation (1)	3.12	0.84	.08	.03	.09	.04	.10	.43**	.23**	.01	-.06	.12*
24. State prove orientation (2)	3.10	0.91	.06	-.01	.02	.06	.08	.44**	.18**	.03	-.04	.10
25. State avoid orientation (1)	2.20	0.89	.04	.06	-.10	.04	-.18**	.33**	.43**	-.08	-.14*	.34**
26. State avoid orientation (2)	2.17	0.95	.03	.01	-.05	-.08	-.19**	.30**	.39**	-.04	-.20**	.36**
27. Self-efficacy (1)	3.73	0.62	-.03	.04	.18**	.02	.22**	.03	-.14**	.12*	.06	-.21**
28. Self-efficacy (2)	3.87	0.63	.07	.03	.10	.09	.30**	.08	-.19**	.13*	.12*	-.25**
29. State anxiety (1)	3.12	1.41	.06	-.01	-.14	-.03	-.07	.09	.10	-.03	-.06	.28**
30. State anxiety (2)	3.04	1.35	.05	-.01	-.10	-.03	-.09	.08	.10	-.01	-.06	.29**

Note: (1) denotes that the variable was measured early in training; (2) denotes the variable was measured at the end of training.

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

Table 4 (cont.)

Means, Standard Deviations, and Intercorrelations for Variables Included in Analyses

Variable	M	SD	1	2	3	4	5	6	7	8	9	10
31. Feelings of control (1)	6.45	1.64	.08	-.04	.01	.08	.28**	.09	-.15**	.09	.16**	-.12*
32. Feelings of control (2)	6.52	1.72	.06	.00	.02	.05	.24**	.04	-.16**	.13*	.17**	-.19**
33. Basic Knowledge (1)	8.81	1.88	.09	.07	-.12*	.38**	.13*	.05	-.09	-.10	.14*	-.01
34. Basic Knowledge (2)	9.81	1.43	.09	.03	-.05	.33**	.16**	.07	-.02	-.02	.07	-.01
35. Strategic Knowledge (1)	6.15	2.51	-.19**	.06	-.13*	.41**	.14**	.05	-.13*	.00	.14**	-.06
36. Strategic Knowledge (2)	8.44	1.87	.05	.01	-.11*	.39**	.14**	-.01	-.10	-.06	.15**	-.09
37. Overall perf. – end of training	0.00	1.00	-.16**	.02	-.05	.31**	.06	-.03	-.10	-.04	.11	-.12*
38. Basic perf – end of training	0.00	1.00	-.17**	.01	-.05	.30**	.06	-.04	-.10	-.04	.11*	.12*
39. Strategic perf. – end of training	0.00	1.00	.02	.09	-.12*	.35**	.05	.11*	.05	-.08	.12*	-.03
40. Overall perf. – near transfer	0.00	1.00	.11*	.02	-.02	.30**	.15**	.04	-.11*	-.05	.09	-.04
41. Basic perf. – near transfer	0.00	1.00	.09	.02	-.02	.29**	.15**	.04	-.11*	-.05	.09	-.04
42. Strategic perf. – near transfer	0.00	1.00	.10	.10	.14*	.37**	.13*	.12*	.00	-.02	.16**	-.03
43. Overall perf. – far transfer	0.00	1.00	.14**	.11*	-.07	.48**	.12*	.09	-.12*	-.13*	.19**	-.07
44. Basic perf. – far transfer	0.00	1.00	.13*	.09	-.09	.44**	.14**	.08	-.13*	-.10	.18**	-.08
45. Strategic perf. – far transfer	0.00	1.00	.12*	.11*	-.08	.37**	.06	.10	-.04	-.07	.13*	-.01

Note: (1) denotes that the variable was measured early in training; (2) denotes the variable was measured at the end of training.

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

Table 4 (cont.)

Means, Standard Deviations, and Intercorrelations for Variables Included in Analyses

Variable	11	12	13	14	15	16	17	18	19	20	21	22
11. Hypothesis-testing (1)	--											
12. Hypothesis-testing (2)	.53**	--										
13. Metacognitive activity (1)	.44**	.55**	--									
14. Metacognitive activity (2)	.34**	.63**	.67**	--								
15. Cognitive effort (1)	.04	.02	.06	-.02	--							
16. Cognitive effort (2)	-.08	.01	.06	-.04	.17**	--						
17. Self-evaluation activity (1)	-.01	.03	.08	.04	.00	.14**	--					
18. Self-evaluation activity (2)	.02	.09	.11*	.04	.02	.13*	.41**	--				
19. Intrinsic motivation (1)	.29**	.25**	.38**	.02	.01	.00	.02	.11*	--			
20. Intrinsic motivation (2)	.21**	.37**	.37**	.05	.02	.04	.01	.23**	.73**	--		
21. State learning orientation (1)	.29**	.32**	.38**	.09	-.03	-.03	.07	.05	.41**	.39**	--	
22. State learning orientation (2)	.27**	.40**	.38**	.02	.03	.09	.07	.14**	.36**	.41**	.70**	--
23. State prove orientation (1)	.20**	.15**	.22**	.00	.05	.05	.05	.05	.18**	.09	.25**	.18**
24. State prove orientation (2)	.15**	.15**	.23**	.03	.08	.08	.03	.10	.19**	.18**	.20**	.23**
25. State avoid orientation (1)	-.02	-.02	-.04	-.01	.14**	.13*	-.03	.05	-.08	-.11*	-.16**	-.08

Note: (1) denotes that the variable was measured early in training; (2) denotes the variable was measured at the end of training.

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

Table 4 (cont.)

Means, Standard Deviations, and Intercorrelations for Variables Included in Analyses

Variable	11	12	13	14	15	16	17	18	19	20	21	22
26. State avoid orientation (2)	.03	.01	.00	.01	.12*	.11*	.01	.05	-.08	-.11*	-.08	-.01
27. Self-efficacy (1)	.29**	.24**	.27**	.21**	-.11*	-.23**	-.01	-.01	.28**	.15**	.36**	.31**
28. Self-efficacy (2)	.22**	.36**	.28**	.38**	-.04	-.08	.02	.11*	.17**	.26**	.28**	.37**
29. State anxiety (1)	-.04	-.05**	.11*	.08	.19**	.16**	.07	.13*	.01	.01	-.11*	-.01
30. State anxiety (2)	.03	.00	.08	.08	.15**	.12*	.04	.18**	.08	.08	-.06	.01
31. Feelings of control (1)	.19**	.33**	.38**	.33**	.01	-.05	-.02	.03	.22**	.18**	.23**	.26**
32. Feelings of control (2)	.21**	.35**	.29**	.38**	-.02	-.02	-.02	.10	.18**	.25**	.22**	.23**
33. Basic Knowledge (1)	.04	-.01	.04	-.03	.01	-.11*	.05	.08	.16**	.05	.06	.05
34. Basic Knowledge (2)	.04	.06	.06	.07	.02	-.06	.06	.07	.19**	.17**	.10	.10
35. Strategic Knowledge (1)	.06	.06	.07	-.01	.11*	-.28**	-.03	-.01	.09	.07	.04	.02
36. Strategic Knowledge (2)	.04	.05	.03	-.02	.10	-.10	.09	.16**	.19**	.11*	.04	.07
37. Overall perf. – end of training	.00	-.04	-.04	.03	.06	-.20**	.00	.09	.11*	.19**	.05	-.01
38. Basic perf – end of training	-.01	.04	-.04	.03	.07	-.19**	.00	.09	.11	.19**	.05	-.01
39. Strategic perf. – end of training	.06	.12*	.03	.03	.06	-.18**	-.07	.12*	.12*	.10**	.03	.00
40. Overall perf. – near transfer	.02	.03	.01	.04	.07	-.03	-.03	.04	.09	.11*	.14**	.05

Note: (1) denotes that the variable was measured early in training; (2) denotes the variable was measured at the end of training.

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

Table 4 (cont.)

Means, Standard Deviations, and Intercorrelations for Variables Included in Analyses

Variable	11	12	13	14	15	16	17	18	19	20	21	22
41. Basic perf. – near transfer	.02	.03	.01	.04	.07	-.02	-.03	.05	.08	.11*	.14**	.05
42. Strategic perf. – near transfer	.06	.12*	-.01	.00	-.01	-.08	.02	.17**	.13*	.16**	.03	.04
43. Overall perf. – far transfer	.01	.14**	.06	.10	.11*	-.14**	-.01	.15**	.13*	.21**	.08	.01
44. Basic perf. – far transfer	.01	.14**	.08	.13*	.09	-.10	.00	.12*	.12*	.21**	.09	.02
45. Strategic perf. – far transfer	.06	.16**	.07	.03	.05	-.15**	.05	.19**	.14*	.15**	.03	.02

Note: (1) denotes that the variable was measured early in training; (2) denotes the variable was measured at the end of training.

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

Table 4 (cont.)

Means, Standard Deviations, and Intercorrelations for Variables Included in Analyses

Variable	23	24	25	26	27	28	29	30	31	33	34
23. State prove orientation (1)	--										
24. State prove orientation (2)	.77**	--									
25. State avoid orientation (1)	.31**	.34**	--								
26. State avoid orientation (2)	.36**	.40**	.77**	--							
27. Self-efficacy (1)	.20**	.12*	-.30**	-.20**	--						
28. Self-efficacy (2)	.15**	.15*	-.26**	-.25**	.64**	--					
29. State anxiety (1)	.01	.01	.34**	.24**	-.30**	-.25**	--				
30. State anxiety (2)	.02	.06	.26**	.25**	-.12*	-.19**	.70**	--			
31. Feelings of control (1)	.10	.10	-.16**	-.11*	.43**	.38**	-.09	-.07	--		
32. Feelings of control (2)	.08	.08	-.17**	-.20**	.38**	.46**	-.13*	-.09	.70**	--	
33. Basic Knowledge (1)	.11*	.11*	-.07	-.15**	.23**	.19**	-.12*	-.03	.24**	.11**	--
34. Basic Knowledge (2)	.19**	.19**	-.03	-.05	.09	.15**	-.07	-.03	.15**	.08	.53**
35. Strategic Knowledge (1)	.08	.08**	-.02	-.07	.03	.06	-.02	-.03	.08**	.02	.24**
36. Strategic Knowledge (2)	.00	.00	.01	-.04	.04	.04	.06	.09	.11*	.05	.35**
37. Overall perf. – end of training	-.02	-.02	-.11*	-.19**	.09	.21**	-.08	-.03	.10	.18**	.34**
											.39**

Note: (1) denotes that the variable was measured early in training; (2) denotes the variable was measured at the end of training.

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

Table 4 (cont.)

Means, Standard Deviations, and Intercorrelations for Variables Included in Analyses

Variable	23	24	25	26	27	28	29	30	31	31	33	34
38. Basic perf. – end of training	-.03	.09	-.11	-.18**	.08	.19**	-.08	-.03	.09	.18**	.32**	.38**
39. Strategic perf. – end of training	.10	.09	.04	-.04	.12*	.13*	-.01	.04	.10	.08	.25**	.20**
40. Overall perf. – near transfer	.08	.10	-.04	-.14**	.16**	.26**	-.06	-.01	.20**	.19**	.50**	.47**
41. Basic perf. – near transfer	.08	.09	-.04	-.14**	.16**	.25**	-.05	-.01	.19**	.19**	.49**	.46**
42. Strategic perf. – near transfer	.05	.06	-.01	-.08	.03	.10	-.01	.05	.11*	.09	.32**	.27**
43. Overall perf. – far transfer	.11*	.16**	-.04	-.13*	.16**	.28**	-.09	-.04	.18*	.18**	.43**	.47**
44. Basic perf. – far transfer	.11*	.16**	-.06	-.14**	.15**	.27**	-.07	-.03	.23**	.20**	.47**	.51**
45. Strategic perf. – far transfer	.05	.09	.00	-.07	.10	.15**	-.03	.01	.12*	.13*	.35**	.30**

Note: (1) denotes that the variable was measured early in training; (2) denotes the variable was measured at the end of training.

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

Table 4 (cont.)

Means, Standard Deviations, and Intercorrelations for Variables Included in Analyses

Variable	35	36	37	38	39	40	41	42	43	44	45
35. Strategic Knowledge (1)	--										
36. Strategic Knowledge (2)	.46**	--									
37. Overall perf. – end of training	.27**	.23**	--								
38. Basic perf – end of training	.26**	.22**	.99**	--							
39. Strategic perf. – end of training	.28**	.41**	.15**	.14*	--						
40. Overall perf. – near transfer	.20**	.20**	.51**	.49**	.21**	--					
41. Basic perf. – near transfer	.19**	.19**	.51**	.49**	.20**	.99**	--				
42. Strategic perf. – near transfer	.33**	.49**	.20**	.18**	.73**	.29**	.27**	--			
43. Overall perf. – far transfer	.40**	.41**	.53**	.51**	.51**	.55**	.54**	.57**	--		
44. Basic perf. – far transfer	.35**	.33**	.58**	.57**	.37**	.60**	.59**	.43**	.91**	--	
45. Strategic perf. – far transfer	.36**	.52**	.26**	.24**	.71**	.30**	.29**	.80**	.69**	.52**	--

Note: (1) denotes that the variable was measured early in training; (2) denotes the variable was measured at the end of training.

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

Table 5

Hierarchical Regression Results for Error Training Elements on Overall Performance

Variable	<u>B</u>	<u>SE B</u>	<u>β</u>	<u>ΔR²</u>	<u>R²</u>
DV: Overall Performance End of Training					
1. Cognitive ability	0.427**	0.078	.297	.109*	.109**
Learning orientation	0.006	0.078	.005		
Performance-prove orientation	-0.026	0.058	-.027		
Performance-avoid orientation	-0.008	0.063	-.008		
Conscientiousness	-0.024	0.069	-.020		
Openness	0.029	0.073	.023		
Trait Anxiety	-0.194 [†]	0.118	-.096		
2. Instructional element	-0.337**	0.104	-.169	.027*	.137**
Motivational element	0.006	0.102	.003		
Emotional element	-0.035	0.102	-.017		
3. Instructional x Motivational	-0.030	0.204	-.013	.000	.137**
DV: Overall Performance Near Transfer					
1. Cognitive ability	0.400**	0.078	.278	.108**	.108**
Learning orientation	0.157*	0.078	.123		
Performance-prove orientation	0.017	0.058	.017		
Performance-avoid orientation	-0.060	0.063	-.059		
Conscientiousness	-0.050	0.069	-.042		
Openness	-0.051	0.073	-.041		
Trait Anxiety	0.021	0.118	.010		
2. Instructional element	0.172	0.105	.086	.007	.115**
Motivational element	0.024	0.103	.012		
Emotional element	-0.020	0.104	-.010		
3. Instructional x Motivational	-0.217	0.206	-.094	.003	.118**
DV: Overall Performance Far Transfer					
1. Cognitive ability	0.615**	0.072	.428	.253**	.253**
Learning orientation	0.013	0.072	.010		
Performance-prove orientation	0.105*	0.053	.109		
Performance-avoid orientation	-0.082	0.058	-.081		
Conscientiousness	-0.101	0.063	-.085		
Openness	0.075	0.066	.059		
Trait Anxiety	-0.104	0.108	-.051		
2. Instructional element	0.240*	0.095	.120	.024*	.277**
Motivational element	0.204*	0.093	.102		
Emotional element	-0.057	0.094	-.028		
3. Instructional x Motivational	-0.123	0.186	-.053	.001	.278**

Note. N = 350. The B weights in the columns are from the step of entry into the model. Continuous predictors were mean centered and performance outcomes were standardized.

[†] p < .10. * p < .05. ** p < .01.

Table 6

Hierarchical Regression Results for Error Training Elements on Basic and Strategic Performance Composites in Near and Far Transfer Trials

Variable	B	SE B	β	ΔR^2	R^2
DV: Basic Performance Near Transfer					
1. Cognitive ability	0.380**	0.079	.264	.099**	.099**
Learning orientation	0.146 [†]	0.079	.114		
Performance-prove orientation	0.018	0.058	.019		
Performance-avoid orientation	-0.063	0.064	-.063		
Conscientiousness	-0.055	0.069	-.046		
Openness	-0.047	0.073	-.037		
Trait Anxiety	0.018	0.118	.009		
2. Instructional element	0.149	0.106	.074	.005	.105**
Motivational element	0.023	0.104	.012		
Emotional element	-0.024	0.104	-.012		
3. Instructional x Motivational	-0.227	0.207	-.098	.003	.108**
DV: Strategic Performance Near Transfer					
1. Cognitive ability	0.515**	0.076	.358	.161**	.161**
Learning orientation	0.055	0.076	.043		
Performance-prove orientation	0.067	0.056	.069		
Performance-avoid orientation	0.067	0.061	.067		
Conscientiousness	0.048	0.067	.041		
Openness	0.104	0.070	.083		
Trait Anxiety	-0.038	0.114	-.019		
2. Instructional element	0.132	0.101	.066	.022*	.183**
Motivational element	0.174 [†]	0.099	.087		
Emotional element	-0.217*	0.100	-.109		
3. Instructional x Motivational	-0.144	0.198	-.062	.001	.185**
DV: Basic Performance Far Transfer					
1. Cognitive ability	0.556**	0.073	.387	.212**	.212**
Learning orientation	0.050	0.074	.039		
Performance-prove orientation	0.085	0.054	.089		
Performance-avoid orientation	-0.071	0.060	-.070		
Conscientiousness	-0.086	0.065	-.072		
Openness	-0.065	0.068	.052		
Trait Anxiety	-0.124	0.111	-.061		
2. Instructional element	0.227*	0.098	.114	.022*	.234**
Motivational element	0.174 [†]	0.096	.087		
Emotional element	-0.119	0.096	-.060		
3. Instructional x Motivational	-0.094	0.192	-.041	.001	.235**

Note. N = 350. The B weights in the columns are from the step of entry into the model. Continuous predictors were mean centered and performance outcomes were standardized.

[†] $p < .10$. * $p < .05$. ** $p < .01$.

Table 6 (cont.)

Hierarchical Regression Results for Error Training Elements on Basic and Strategic Performance Composites in Near and Far Transfer Trials

Variable	<u>B</u>	<u>SE B</u>	<u>β</u>	<u>ΔR^2</u>	<u>R^2</u>
DV: Strategic Performance Far Transfer					
1. Cognitive ability	0.506**	0.076	.352	.147**	.147**
Learning orientation	-0.038	0.077	-.030		
Performance-prove orientation	0.088	0.056	.092		
Performance-avoid orientation	-0.029	0.062	-.028		
Conscientiousness	-0.011	0.067	-.009		
Openness	0.065	0.071	.052		
Trait Anxiety	0.002	0.115	-.001		
2. Instructional element	0.195 [†]	0.102	.097	.019*	.166**
Motivational element	0.195 [†]	0.100	.097		
Emotional element	-0.083	0.101	-.041		
3. Instructional x Motivational	-0.098	0.200	-.043	.001	.167**

Note. N = 350. The B weights in the columns are from the step of entry into the model. Continuous predictors were mean centered and performance outcomes were standardized.

[†] $p < .10$. * $p < .05$. ** $p < .01$.

Table 7

Hierarchical Regression Results for Error Training Elements on Basic and Strategic Knowledge

Variable	<u>B</u>	<u>SE B</u>	<u>β</u>	<u>ΔR^2</u>	<u>R^2</u>
DV: Basic Knowledge					
1. Cognitive ability	0.679**	0.110	.331	.127**	.127**
Learning orientation	0.271*	0.111	.149		
Performance-prove orientation	-0.015	0.081	-.011		
Performance-avoid orientation	0.071	0.089	.049		
Conscientiousness	0.016	0.097	.010		
Openness	-0.081	0.102	-.045		
Trait Anxiety	0.082	0.166	.028		
2. Instructional element	0.164	0.148	.057	.005	.132**
Motivational element	0.032	0.146	.011		
Emotional element	-0.121	0.147	-.043		
3. Instructional x Motivational	0.505 [†]	0.290	.153	.008 [†]	.139**
DV: Strategic Knowledge					
1. Cognitive ability	0.989**	0.141	.368	.166**	.166**
Learning orientation	0.211	0.142	.088		
Performance-prove orientation	-0.085	0.104	-.047		
Performance-avoid orientation	0.021	0.114	.011		
Conscientiousness	-0.064	0.124	-.029		
Openness	0.058	0.131	.025		
Trait Anxiety	-0.197	0.213	-.052		
2. Instructional element	0.153	0.189	.041	.008	.174**
Motivational element	-0.071	0.186	.002		
Emotional element	-0.318	0.187	-.085		
3. Instructional x Motivational	0.351	0.372	.081	.002	.176**

Note. N = 350. Knowledge outcomes above are those measured at the end of training. The B weights in the columns are from the step of entry into the model. Continuous predictors were mean centered.

[†] $p < .10$. * $p < .05$. ** $p < .01$.

Table 8

Hierarchical Regression Results for Error Training Elements on Cognitive Training Processes

Variable	<u>B</u>	<u>SE B</u>	<u>β</u>	<u>ΔR²</u>	<u>R²</u>
DV: Hypothesis-testing					
1. Cognitive ability	-0.079	0.086	-.050	.096**	.096**
Learning orientation	0.159 [†]	0.087	.113		
Performance-prove orientation	0.044	0.063	.041		
Performance-avoid orientation	-0.020	0.069	-.018		
Conscientiousness	0.222**	0.073	.168		
Openness	0.261**	0.081	.188		
2. Instructional element	0.122	0.115	.055	.003	.099**
Motivational element	0.025	0.114	.011		
3. Instructional x Motivational	-0.218	0.229	-.086	.002	.101**
DV: Metacognitive Activity					
1. Cognitive ability	-0.105 [†]	0.057	-.100	.092**	.092**
Learning orientation	0.142*	0.057	.152		
Performance-prove orientation	-0.033	0.042	.047		
Performance-avoid orientation	-0.017	0.045	-.023		
Conscientiousness	0.106*	0.048	.122		
Openness	0.144**	0.053	.157		
2. Instructional element	0.215**	0.075	.148	.022*	.115**
Motivational element	0.055	0.075	.038		
3. Instructional x Motivational	0.048	0.150	.028	.000	.115**
DV: Cognitive Effort					
1. Cognitive ability	-26.971*	12.644	-.119	.050**	.050**
Learning orientation	6.109	12.728	.030		
Performance-prove orientation	17.017 [†]	9.276	.112		
Performance-avoid orientation	15.783	10.069	.099		
Conscientiousness	7.095	10.706	.038		
Openness	22.406 [†]	11.805	.113		
2. Instructional element	148.791**	14.883	.472	.215**	.265**
Motivational element	-2.396	14.755	-.008		
3. Instructional x Motivational	36.109	29.545	.099	.003	.268**

Note. N = 350. Processes above measured at the end of training. The B weights in the columns are from the step of entry into the model. Continuous predictors were mean centered.

[†] $p < .10$. * $p < .05$. ** $p < .01$.

Table 8 (cont.)

Hierarchical Regression Results for Error Training Elements on Cognitive Training Processes

Variable	<u>B</u>	<u>SE B</u>	<u>β</u>	<u>ΔR²</u>	<u>R²</u>
DV: Self-Evaluation Activity					
1. Cognitive ability	4.456	3.715	.068	.008	.008
Learning orientation	-0.157	3.739	-.003		
Performance-prove orientation	-0.115	2.725	-.003		
Performance-avoid orientation	-0.590	2.958	-.013		
Conscientiousness	2.658	3.145	.049		
Openness	1.426	3.468	.025		
2. Instructional element	3.442	4.966	.038	.003	.010
Motivational element	-3.224	4.923	-.036		
3. Instructional x Motivational	23.933*	9.793	.228	.017*	.027

Note. N = 350. Processes above measured at the end of training. The B weights in the columns are from the step of entry into the model. Continuous predictors were mean centered.

[†] p < .10. * p < .05. ** p < .01.

Table 9

Hierarchical Regression Results for Error Training Elements on Motivational Training Processes

Variable	B	SE B	β	ΔR^2	R^2
DV: Intrinsic Motivation					
1. Cognitive ability	0.042	0.107	.022	.038*	.038*
Learning orientation	0.201 [†]	0.103	.117		
Performance-prove orientation	-0.035	0.080	-.027		
Performance-avoid orientation	-0.042	0.088	-.031		
Conscientiousness	0.150	0.094	.094		
Trait Anxiety	-0.097	0.163	-.036		
2. Instructional element	0.153	0.146	.057	.004	.042 [†]
Motivational element	0.086	0.143	.032		
3. Instructional x Motivational	-0.591*	0.284	-.191	.012*	.054*
DV: State Performance-Avoid Orientation					
1. Cognitive ability	-0.019	0.067	-.014	.248**	.248**
Learning orientation	-0.166**	0.064	-.138		
Performance-prove orientation	0.175**	0.050	.192		
Performance-avoid orientation	0.185**	0.055	.194		
Conscientiousness	0.089	0.058	.079		
Trait Anxiety	0.479**	0.102	.250		
2. Instructional element	-0.064	0.091	-.034	.001	.250**
Motivational element	-0.011	0.090	-.006		
3. Instructional x Motivational	0.174	0.178	.080	.002	.252**
DV: State Learning Orientation					
1. Cognitive ability	-0.063	0.061	-.054	.170**	.170**
Learning orientation	0.325**	0.058	.311		
Performance-prove orientation	-0.054	0.045	-.069		
Performance-avoid orientation	-0.085 [†]	0.049	-.103		
Conscientiousness	0.152**	0.053	.157		
Trait Anxiety	0.045	0.092	.027		
2. Instructional element	0.055	0.082	.034	.005	.175**
Motivational element	0.104	0.081	.064		
3. Instructional x Motivational	0.163	0.161	.086	.002	.178**

Note. N = 350. Processes above measured at the end of training. The B weights in the columns are from the step of entry into the model. Continuous predictors were mean centered.

[†] $p < .10$. * $p < .05$. ** $p < .01$.

Table 9 (cont.)

Hierarchical Regression Results for Error Training Elements on Motivational Training Processes

Variable	<u>B</u>	<u>SE B</u>	<u>β</u>	<u>ΔR^2</u>	<u>R^2</u>
DV: State Performance-Prove Orientation					
1. Cognitive ability	0.036	0.067	.028	.193**	.193**
Learning orientation	0.006	0.064	.005		
Performance-prove orientation	0.374**	0.050	.428		
Performance-avoid orientation	0.010	0.054	.010		
Conscientiousness	0.013	0.058	.012		
Trait Anxiety	0.028	0.102	.015		
2. Instructional element	-0.027	0.091	-.015	.000	.193**
Motivational element	-0.001	0.089	-.001		
3. Instructional x Motivational	-0.105	0.178	-.050	.001	.194**
DV: Self-Efficacy					
1. Cognitive ability	0.021	0.047	.024	.146**	.146**
Learning orientation	0.165**	0.045	.206		
Performance-prove orientation	0.076*	0.035	.126		
Performance-avoid orientation	-0.068 [†]	0.038	-.107		
Conscientiousness	0.023	0.041	.003		
Trait Anxiety	-0.252**	0.072	-.199		
2. Instructional element	0.080	0.064	.064	.007	.152**
Motivational element	0.069	0.063	.055		
3. Instructional x Motivational	-0.039	0.125	-.027	.000	.153**

Note. N = 350. Processes above measured at the end of training. The B weights in the columns are from the step of entry into the model. Continuous predictors were mean centered.

[†] $p < .10$. * $p < .05$. ** $p < .01$.

Table 10

Hierarchical Regression Results for Error Training Elements on Emotional Training Processes

Variable	<u>B</u>	<u>SE B</u>	<u>β</u>	<u>ΔR^2</u>	<u>R^2</u>
DV: State Anxiety					
1. Cognitive ability	-0.018	0.102	-.009	.086**	.086**
Learning orientation	-0.082	0.099	-.048		
Performance-prove orientation	0.051	0.078	.039		
Performance-avoid orientation	-0.039	0.086	-.028		
Trait Anxiety	0.770**	0.153	.281		
2. Motivational element	-0.067	0.140	-.025	.009	.095**
Emotional element	-0.258 [†]	0.141	-.095		
DV: Feelings of Control					
1. Cognitive ability	-0.001	0.131	.000	.084**	.084**
Learning orientation	0.375**	0.127	.170		
Performance-prove orientation	0.130	0.100	.078		
Performance-avoid orientation	-0.156	0.110	-.090		
Trait Anxiety	-0.488*	0.195	-.140		
2. Emotional element	-0.019	0.180	-.006	.000	.084**

Note. N = 350. Processes above measured at the end of training. The B weights in the columns are from the step of entry into the model. Continuous predictors were mean centered.

[†] $p < .10$. * $p < .05$. ** $p < .01$.

Table 11

Selected Hierarchical Regression Results for Interactive Effects of Error Training Elements and Cognitive Ability

Variable	B	SE B	β	ΔR^2	R^2
DV: Strategic Performance Far Transfer					
1. Individual Differences				.147**	.147**
2. Error Training Elements				.019*	.166**
3. Instructional x Ability	-0.291*	0.143	-.141	.010	.176*
Emotional x Ability	-0.019	0.143	-.010		
DV: Strategic Knowledge					
1. Individual Differences				.166**	.166**
2. Error Training Elements				.008	.174**
3. Instructional x Ability	-0.662*	0.264	-.171	.023**	.197**
Emotional x Ability	0.528*	0.265	.140		
DV: Metacognitive Activity					
1. Individual Differences				.092**	.092**
2. Error Training Elements				.022*	.115**
3. Instructional x Ability	0.207 [†]	0.107	.137	.010 [†]	.124**
DV: Feelings of Control					
1. Individual Differences				.084**	.084**
2. Error Training Elements				.000	.084**
3. Emotional x Ability	-0.641*	0.256	-.184	.017*	.101**

Note. N = 350. The steps for the individual differences and error training elements summarize the overall variance explained. Regression weights for specific individual differences and error training elements included in each step can be found in previous tables. The B weights in the columns are from the step of entry into the model.

Continuous predictors were mean centered and performance outcomes were standardized.

[†] $p < .10$. * $p < .05$. ** $p < .01$.

Table 12

Selected Hierarchical Regression Results for Interactive Effects of Error Training Elements and Trait Learning Orientation

Variable	B	SE B	β	ΔR^2	R^2
DV: Strategic Performance Near Transfer					
1. Individual Differences				.161**	.161**
2. Error Training Elements				.022*	.183**
3. Instructional x Learning Orientation	-0.245 [†]	0.128	-.124	.011 [†]	.195**
Motivational x Learning Orientation	0.115	0.127	.064		
DV: Strategic Performance Far Transfer					
1. Individual Differences				.147**	.147**
2. Error Training Elements				.019*	.166**
3. Instructional x Learning Orientation	-0.282*	0.130	-.143	.013 [†]	.179**
Motivational x Learning Orientation	0.066	0.128	.037		
DV: Hypothesis-Testing					
1. Individual Differences				.096**	.096**
2. Error Training Elements				.003	.099**
3. Instructional x Learning Orientation	-0.270 [†]	0.148	-.124	.009 [†]	.108**
DV: Self-Evaluation Activity					
1. Individual Differences				.008	.008
2. Error Training Elements				.003	.010
3. Instructional x Learning Orientation	-11.861 [†]	6.380	-.133	.010 [†]	.020
DV: Intrinsic Motivation					
1. Individual Differences				.038*	.038*
2. Error Training Elements				.004	.042 [†]
3. Instructional x Learning Orientation	-0.333 [†]	0.185	-.126	.016 [†]	.058*
Motivational x Learning Orientation	-0.323 [†]	0.183	-.134		
DV: State Performance-Prove Orientation					
1. Individual Differences				.193**	.193**
2. Error Training Elements				.000	.193**
3. Motivational x Learning Orientation	-0.286*	0.113	-.175	.015*	.208**

Note. N = 350. The steps for the individual differences and error training elements summarize the overall variance explained. Regression weights for specific individual differences and error training elements included in each step can be found in previous tables. The B weights in the columns are from the step of entry into the model.

Continuous predictors were mean centered and performance outcomes were standardized.

[†] $p < .10$. * $p < .05$. ** $p < .01$.

Table 12 (cont.)

Selected Hierarchical Regression Results for Interactive Effects of Error Training Elements and Trait Learning Orientation

Variable	<u>B</u>	<u>SE B</u>	<u>β</u>	<u>ΔR²</u>	<u>R²</u>
DV: State Learning Orientation (early)					
1. Individual Differences				.152**	.152**
2. Error Training Elements				.004	.155**
3. Motivational x Learning Orientation	-0.248*	0.104	-.169	.014*	.169**

Note. N = 350. The steps for the individual differences and error training elements summarize the overall variance explained. Regression weights for specific individual differences and error training elements included in each step can be found in previous tables. The B weights in the columns are from the step of entry into the model. Continuous predictors were mean centered and performance outcomes were standardized.
[†] $p < .10$. * $p < .05$. ** $p < .01$.

Table 13

Selected Hierarchical Regression Results for Interactive Effects of Error Training Elements and Trait Performance-Avoid Orientation

Variable	<u>B</u>	<u>SE B</u>	<u>β</u>	<u>ΔR^2</u>	<u>R^2</u>
DV: Basic Performance Near Transfer					
1. Individual Differences				.099**	.099**
2. Error Training Elements				.005	.105**
3. Instructional x Performance-Avoid	-0.211*	0.104	-.148	.012	.117**
Motivational x Performance-Avoid	0.077	0.104	.052		
DV: Basic Knowledge (early)					
1. Individual Differences				.154**	.154**
2. Error Training Elements				.016 [†]	.169**
3. Instructional x Performance-Avoid	-0.318 [†]	0.189	-.118	.017*	.186**
Motivational x Performance-Avoid	0.389*	0.189	.140		
DV: Strategic Knowledge					
1. Individual Differences				.166**	.166**
2. Error Training Elements				.008	.174**
3. Instructional x Performance-Avoid	0.354 [†]	0.188	.133	.009	.183**
Motivational x Performance-Avoid	-0.073	0.188	-.027		
DV: State Performance-Avoid (early)					
1. Individual Differences				.268**	.268**
2. Error Training Elements				.002	.271**
3. Motivational x Performance-Avoid	0.196*	0.083	.149	.012*	.282**
DV: State Performance-Avoid (later)					
1. Individual Differences				.248**	.248**
2. Error Training Elements				.001	.250**
3. Motivational x Performance-Avoid	0.181*	0.090	.129	.009*	.258**

Note. N = 350. The steps for the individual differences and error training elements summarize the overall variance explained. Regression weights for specific individual differences and error training elements included in each step can be found in previous tables. The B weights in the columns are from the step of entry into the model. Continuous predictors were mean centered and performance outcomes were standardized.
[†] $p < .10$. * $p < .05$. ** $p < .01$.

Table 14

Selected Hierarchical Regression Results for Interactive Effects of Error Training Elements and Openness to Experience

Variable	<u>B</u>	<u>SE B</u>	<u>β</u>	<u>ΔR^2</u>	<u>R^2</u>
DV: Targets Engaged Near Transfer					
1. Individual Differences				.037 [†]	.037 [†]
2. Error Training Elements				.046**	.083**
3. Instructional x Openness	0.383 [†]	0.198	.145	.010 [†]	.093**
DV: Targets Engaged Far Transfer					
1. Individual Differences				.042*	.042*
2. Error Training Elements				.025*	.067**
3. Instructional x Openness	1.105*	0.541	.154	.011*	.079**

Note. N = 350. The steps for the individual differences and error training elements summarize the overall variance explained. Regression weights for specific individual differences and error training elements included in each step can be found in previous tables. The B weights in the columns are from the step of entry into the model. Continuous predictors were mean centered and performance outcomes were standardized.
[†] $p < .10$. * $p < .05$. ** $p < .01$.

Table 15

Selected Hierarchical Regression Results for Interactive Effects of Error Training Elements and Conscientiousness

Variable	<u>B</u>	<u>SE B</u>	<u>β</u>	<u>ΔR^2</u>	<u>R^2</u>
DV: Basic Performance Near Transfer					
1. Individual Differences				.099**	.099**
2. Error Training Elements				.005	.105**
3. Instructional x Conscientiousness	0.279*	0.123	.157	.015 [†]	.120**
Motivational x Conscientiousness	0.119	0.123	.071		

Note. N = 350. The steps for the individual differences and error training elements summarize the overall variance explained. Regression weights for specific individual differences and error training elements included in each step can be found in previous tables. The B weights in the columns are from the step of entry into the model.

Continuous predictors were mean centered and performance outcomes were standardized.

[†] $p < .10$. * $p < .05$. ** $p < .01$.

Table 16

Selected Hierarchical Regression Results for Interactive Effects of Error Training Elements and Trait Anxiety

Variable	<u>B</u>	<u>SE B</u>	<u>β</u>	<u>ΔR^2</u>	<u>R^2</u>
DV: Feelings of Control					
1. Individual Differences				.084**	.084**
2. Error Training Elements				.000	.084**
3. Emotional x Trait Anxiety	0.585 [†]	0.363	.125	.007 [†]	.091*

Note. N = 350. The steps for the individual differences and error training elements summarize the overall variance explained. Regression weights for specific individual differences and error training elements included in each step can be found in previous tables. The B weights in the columns are from the step of entry into the model. Continuous predictors were mean centered and performance outcomes were standardized.

[†] $p < .11$. * $p < .05$. ** $p < .01$.

Table 17

Hierarchical Regression Results for Incremental Effects of Instructional Antecedents and Instructional Processes on Knowledge and Performance

Variable	R^2	ΔR^2
DV: Basic Performance – Near Transfer		
1. Cognitive Ability	.083**	.083**
2. Instructional Antecedents	.143**	.060 [†]
3. Instructional Processes	.145**	.002
DV: Strategic Performance – Near Transfer		
1. Cognitive Ability	.140**	.140**
2. Instructional Antecedents	.195**	.055 [†]
3. Instructional Processes	.243**	.048**
DV: Strategic Performance – Near Transfer		
1. Cognitive Ability	.140**	.140**
2. Instructional Processes	.186**	.046**
3. Instructional Antecedents	.243**	.057*
DV: Basic Performance – Far Transfer		
1. Cognitive Ability	.191**	.191**
2. Instructional Antecedents	.245** ^a	.054 [†]
3. Instructional Processes	.288**	.043**
DV: Basic Performance – Far Transfer		
1. Cognitive Ability	.191**	.191**
2. Instructional Processes	.230**	.039**
3. Instructional Antecedents	.288**	.058*
DV: Strategic Performance – Far Transfer		
1. Cognitive Ability	.139**	.139**
2. Instructional Antecedents	.191**	.052 [†]
3. Instructional Processes	.280**	.089**
DV: Strategic Performance – Far Transfer		
1. Cognitive Ability	.139**	.139**
2. Instructional Processes	.211**	.073**
3. Instructional Antecedents	.280**	.069**

Note. N = 350. Instructional antecedents include instructional element, motivational element, instruction X motivation, trait learning, trait performance-prove, trait performance-avoid, conscientiousness, openness, instruction X cognitive ability, instruction X learning, instruction X prove, instruction X avoid, instruction x openness, and instruction X conscientiousness. Instructional processes include hypothesis-testing, metacognitive activity, cognitive effort, and self-evaluation activity. Motivation was included only to partial its linear effect from the instruction X motivation interaction.

[†] $p < .10$. * $p < .05$. ** $p < .01$.

Table 17 (cont.)

Hierarchical Regression Results for Incremental Effects of Instructional Antecedents and Instructional Processes on Knowledge and Performance

Variable	R^2	ΔR^2
DV: Basic Knowledge		
1. Cognitive Ability	.108**	.108**
2. Instructional Antecedents	.150**	.042
3. Instructional Processes	.163**	.013
DV: Strategic Knowledge		
1. Cognitive Ability	.152**	.152**
2. Instructional Antecedents	.191**	.039
3. Instructional Processes	.219**	.028*

Note. N = 350. Instructional antecedents include instructional element, motivational element, instruction X motivation, trait learning, trait performance-prove, trait performance-avoid, conscientiousness, openness, instruction X cognitive ability, instruction X learning, instruction X prove, instruction X avoid, instruction x openness, and instruction X conscientiousness. Instructional processes include hypothesis-testing, metacognitive activity, cognitive effort, and self-evaluation activity. Motivation included only to partial its linear effect from the instruction X motivation interaction.

[†] $p < .10$. * $p < .05$. ** $p < .01$.

Table 18

Hierarchical Regression Results for Incremental Effects of Motivational Antecedents and State Goal Orientation on Self-Efficacy and Intrinsic Motivation

Variable	R^2	ΔR^2
DV: Self-Efficacy		
1. Cognitive Ability	.008 [†]	.008 [†]
2. Motivational Antecedents	.162**	.154**
3. State Goal Orientation	.284**	.123**
DV: Self-Efficacy		
1. Cognitive Ability	.008 [†]	.008 [†]
2. State Goal Orientation	.237**	.229**
3. Motivational Antecedents	.284**	.047*
DV: Intrinsic Motivation		
1. Cognitive Ability	.001	.001
2. Motivational Antecedents	.062 [†]	.062*
3. State Goal Orientation	.226**	.164**
DV: Intrinsic Motivation		
1. Cognitive Ability	.001	.001
2. State Goal Orientation	.199**	.198**
3. Motivational Antecedents	.226**	.028

Note. N = 350. Motivational antecedents include motivational element, instructional element, instruction X motivation, trait learning, trait performance-prove, trait performance-avoid, conscientiousness, trait anxiety, motivation X learning, motivation X prove, motivation X avoid, and motivation X conscientiousness. State goal orientation includes learning, performance-prove, and performance-avoid. Instruction was included only to partial its linear effect from the instruction X motivation interaction.

[†] $p < .10$. * $p < .05$. ** $p < .01$.

Table 19

Hierarchical Regression Results for Incremental Effects of Motivational Antecedents and Motivational Processes on Knowledge and Performance

Variable	R^2	ΔR^2
DV: Basic Performance – Near Transfer		
1. Cognitive Ability	.083**	.083**
2. Motivational Antecedents	.136**	.053
3. Motivational Processes	.168**	.032**
DV: Strategic Performance – Near Transfer		
1. Cognitive Ability	.140**	.140**
2. Motivational Antecedents	.184**	.044
3. Motivational Processes	.199**	.015*
DV: Basic Performance – Far Transfer		
1. Cognitive Ability	.191**	.191**
2. Motivational Antecedents	.269**	.078**
3. Motivational Processes	.319**	.050**
DV: Basic Performance – Far Transfer		
1. Cognitive Ability	.191**	.191**
2. Motivational Processes	.264**	.073**
3. Motivational Antecedents	.319**	.055*
DV: Strategic Performance – Far Transfer		
1. Cognitive Ability	.139**	.139**
2. Motivational Processes	.178**	.039
3. Motivational Antecedents	.198**	.020*
DV: Basic Knowledge		
1. Cognitive Ability	.108**	.108**
2. Motivational Antecedents	.169**	.060 [†]
3. Motivational Processes	.183**	.015 [†]
DV: Basic Knowledge		
1. Cognitive Ability	.108**	.108**
2. Motivational Processes	.140**	.032**
3. Motivational Antecedents	.183** ^a	.043

Note. N = 350. Motivational antecedents include motivational element, instructional element, instruction X motivation, trait learning, trait performance-prove, trait performance-avoid, conscientiousness, trait anxiety, motivation X learning, motivation X prove, motivation X avoid, motivation X conscientiousness, state learning, state performance-prove, and state performance-avoid. Motivational processes include self-efficacy and intrinsic motivation. Instruction was included only to partial its linear effect from the instruction X motivation interaction.

[†] $p < .10$. * $p < .05$. ** $p < .01$.

Table 19 (cont.)

Hierarchical Regression Results for Incremental Effects of Motivational Antecedents and Motivational Processes on Knowledge and Performance

Variable	R^2	ΔR^2
DV: Strategic Knowledge		
1. Cognitive Ability	.152**	.152**
2. Motivational Antecedents	.174**	.022
3. Motivational Processes	.184**	.010

Note. N = 350. Motivational antecedents include motivational element, instructional element, instruction X motivation, trait learning, trait performance-prove, trait performance-avoid, conscientiousness, trait anxiety, motivation X learning, motivation X prove, motivation X avoid, motivation X conscientiousness, state learning, state performance-prove, and state performance-avoid. Motivational processes include self-efficacy and intrinsic motivation. Instruction was included only to partial its linear effect from the instruction X motivation interaction.

† $p < .10$. * $p < .05$. ** $p < .01$.

Table 20

Hierarchical Regression Results for Incremental Effects of Emotional Antecedents and Emotional Processes on Knowledge and Performance

Variable	R^2	ΔR^2
DV: Basic Performance – Near Transfer		
1. Cognitive Ability	.083**	.083**
2. Emotional Antecedents	.101**	.018
3. Emotional Processes	.122**	.021*
DV: Strategic Performance – Near Transfer		
1. Cognitive Ability	.140**	.140**
2. Emotional Antecedents	.171**	.031 [†]
3. Emotional Processes	.176**	.005
DV: Basic Performance – Far Transfer		
1. Cognitive Ability	.191**	.191**
2. Emotional Antecedents	.210**	.020
3. Emotional Processes	.233**	.023**
DV: Strategic Performance – Far Transfer		
1. Cognitive Ability	.139**	.139**
2. Emotional Antecedents	.147**	.008
3. Emotional Processes	.158**	.011
DV: Basic Knowledge		
1. Cognitive Ability	.108**	.108**
2. Emotional Antecedents	.129**	.021
3. Emotional Processes	.132**	.003
DV: Strategic Knowledge		
1. Cognitive Ability	.152**	.152**
2. Emotional Antecedents	.180**	.028
3. Emotional Processes	.194**	.015*

Note. N = 350. Emotional antecedents include emotional element, trait learning, trait performance-prove, trait performance-avoid, trait anxiety, emotion X cognitive ability, and emotion X trait anxiety. Emotional processes include state anxiety and feelings of control.

[†] $p < .10$. * $p < .05$. ** $p < .01$.

APPENDIX R

Supplementary Error Analyses

In this section, I describe the results of a set of supplementary analyses that explored the effects of errors in the current study. While it has been argued that errors are an important component of error training and many other active learning techniques (Frese et al., 1991; Ivancic & Hesketh, 1995/1996; McDaniel & Schlager, 1990), very few studies in this area have attempted to assess the impact of errors on training effectiveness. The goal of the supplementary analyses, therefore, was to examine the effects that errors had on learning, performance, and the error training mechanisms. In the next section, I briefly describe the errors that participants could make in the current study. I then discuss the results of the supplementary analyses and compare the findings to extant research in this area.

Before each of the three training blocks, participants were given a list of training topics and were told to focus on learning the specified skills or strategies during the upcoming three trials. In addition, participants were given a list of common errors associated with the training topics. Individuals in the proceduralized instruction condition received step-by-step instructions to help them avoid the common errors, while individuals in the exploratory learning condition did not receive any further guidance. Furthermore, individuals in the error encouragement condition were directed to make the common errors, while individuals in the error avoidance condition were told to avoid the common mistakes. Finally, the feedback trainees received following each training trial provided detailed information on those errors highlighted during each training block. There are a broad array of errors that trainees can make on the TANDEM task; however,

the error analyses conducted in this study focused only on those errors outlined before each training session because they were the most salient errors to participants and also the most critical errors within the TANDEM domain.

The first training session focused trainees' attention on learning how to prosecute targets. Participants needed to learn the target cue values and the proper procedure for gathering information and executing decisions for each target. Thus, the major errors that one could make during the first training session revolved around target decision-making. Specific errors included (1) making incorrect target decisions; (2) making decisions based on a single cue value; and (3) making target decisions too quickly. These errors occur primarily at the knowledge-base level of regulation, because trainees do not possess adequate knowledge of the cue values or decision-making rules. However, they can also occur at the sensorimotor level because trainees move too quickly and select an incorrect menu option.

The second training session focused trainees' attention on learning some of the more strategic aspects of the task. The overall objective was learning how to identify and monitor the defensive perimeters. Specific learning objectives included using the zoom function to maintain awareness of the overall task situation, using marker targets to identify the outer defensive perimeter, and monitoring the radar screen for pop-up targets. Thus, the major errors that participants could make included (1) prosecuting a large number of targets around the inner defensive perimeter; (2) preventing all targets from crossing the inner perimeter while allowing all targets to cross the outer perimeter; and (3) ignoring the pop-up targets. These errors occur primarily at the knowledge-base level of regulation because trainees do not yet possess adequate knowledge of the different task

components (e.g., zooming, marker targets) necessary to monitor the defensive perimeters.

In the third and final training session, participants were encouraged to learn the strategies that lead to optimal task performance. Participants needed to learn how to identify high priority targets (e.g., targets moving fast and near perimeters) and how to make trade-offs between targets approaching the inner and outer perimeters. Whereas the second training session focused on the fundamental skills needed to protect the perimeters, the strategies highlighted in the third training session are critical to achieving a high level of proficiency on the more complex aspects of the task. The major errors in session three included (1) prosecuting a large number of low priority targets; and (2) allowing a large number of targets to cross the defensive perimeters. These errors occur primarily at the rule-based level of regulation because trainees apply a strategy that is inappropriate for the current task situation.

Using quantitative data collected from the task, indicator variables were created for each of the errors described above. The error indicators were then standardized and combined to create an overall error composite. Trainees who scored higher on the error composite made more errors during training. As noted previously, individuals who received exploratory learning and error encouragement made more errors during training. Analyses were also conducted to examine the effects of these two manipulations on errors committed during each training session. The results revealed the individuals who received exploratory learning and error encouragement made more errors in each of the three training sessions. Interestingly, both manipulations had the biggest effect on the number of decision-making errors trainees made during the first training session. In the

case of the instructional manipulation, this finding may be due to the fact that during the first block trainees were unfamiliar with the task and the guidance provided by the proceduralized instructions was probably more critical to effective performance. In the case of the motivational manipulation, trainees may have been more likely to commit decision-making errors because these errors were extremely salient during training and also the easiest errors to intentionally commit.

The results above demonstrate that the instructional and motivational manipulations led trainees to make more errors during training, as expected. Given this finding, a question that arises is what impact the errors had on learning, performance, and the error training mechanisms. Recent research on error training suggests that errors do not have instructional value in and of themselves. Ivancic and Hesketh (in press), for example, found that showing trainees errors committed by others did not increase learning or performance. Also, Frese (2002) examined the results from a number of his studies on error training and found that the relationship between errors and later learning and performance was negative. Analyses conducted in the present study yielded similar results. The overall error composite and the error composites for each of the three training sessions related negatively to trainees' knowledge as well as their performance during the transfer trials. In addition, errors had a negative effect on a number of the error training mechanisms, such as intrinsic motivation, self-efficacy, and cognitive activity.

These findings suggest that the positive effects of error training do not result simply from making more errors. This is consistent with the fundamental premise of error training – errors have a host of negative consequences that should be managed

during training. Indeed, a greater number of errors committed during training is probably more indicative of a failure to learn important task material than enhanced learning activity. Thus, it appears that just increasing the number of errors that trainees make during training does not directly enhance training effectiveness.

Yet, theoretical work on error training, and in related errors such as exploratory learning, suggests that errors can have positive consequences, such as enhancing mental models, increasing cognitive activity, and helping trainees to discover task strategies that facilitate farther transfer (Frese, 1995; Ivancic & Hesketh, 1995/1996; McDaniel & Schlager, 1990). In addition, work on error training would argue that errors can have positive effects if their negative consequences are managed. However, the effects of errors during training are probably contingent on a number of factors. For example, a trainee who makes a specific type of error, at a certain point in training, and exhibits a particular response to the error (e.g., increases metacognitive activity) may indeed experience enhanced learning and performance. In other words, while more errors may not be better, specific types of errors may have positive effects.

It is extremely difficult, however, to adequately take into consideration the multitude of factors that may influence the effects of errors in training. As a result, most studies that have explored the effects of errors have examined errors in the aggregate. A few studies, however, have attempted to examine errors and their effects at a finer level of detail. Irmer et al. (1992), for example, used key-stroke analyses to explore the exploration patterns of individuals who did and did not receive error training. Also, McDaniel and Schlager (1990) examined the extent to which exploratory learning influenced the time it took trainees to adopt a new task approach in a transfer

environment. While such analyses are beyond the scope of the current study, I did conduct some exploratory analyses in an attempt to better understand the factors that may have influenced the effects of errors in the current study.

One set of analyses I conducted explored potential interactions between the instructional and motivational manipulations and the errors trainees committed during training. A hypothesis that could be proposed is that errors are more beneficial for trainees who receive exploratory learning and error encouragement, because the negative consequences of errors are managed through these training interventions. These analyses revealed a significant interactive effect of the overall error composite and the instructional manipulation on trainees' knowledge. The nature of this interaction was such that the relationship between errors and knowledge was only negative for trainees who received proceduralized instruction. Trainees who received exploratory instruction displayed similar levels of knowledge regardless of the number of errors they made. This provides some minimal evidence that errors may have been more beneficial, or at least less detrimental, for trainees given exploratory instruction. Overall, however, these analyses did not yield many significant results. This is probably due to the fact that the error indicators were rather broad in scope.

A second issue I explored was whether the type and timing of errors had any effect on learning, performance, and the training mechanisms. Some interesting results emerged from these analyses. For example, individuals encouraged to make errors made the most number of incorrect decisions in the first trial. In addition, incorrect decisions only had a negative effect on basic knowledge and the training mechanisms, such as intrinsic motivation, when made in trials 2 and 3. Together, these results suggest that

individuals encouraged to make incorrect decisions may have intentionally done so during trial 1 and, therefore, incorrect decisions made in trial 1 were not associated with the same negative consequences as those made in trials 2 and 3.

Similar results emerged in the second and third training blocks. The effects of exploratory learning and error encouragement on number of errors committed tended to be greatest during the first trial of each training block. This may be because the learning curve was more gradual for individuals given exploratory learning and individuals encouraged to make errors may have used the first trial of each block as an opportunity to make errors and the other two trials as a chance to discover solutions to the errors. Furthermore, the effects of the errors committed during the second and third training blocks tended to be more detrimental when made during the last two trials of the block. For example, ignoring pop-up targets in trial 4 was positively related to strategic knowledge and several other outcomes, but ignoring pop-up targets in trials 5 and 6 tended to have negative effects.

Different effects were also found for different types of errors. For example, focusing a considerable amount of attention on targets near the inner perimeter tended to produce positive effects, particularly when this error was committed early in the second training session. Other errors, such as engaging low priority targets, had rather pervasive negative effects independent of the manipulations and when they were committed. These results may be tied to the fact that different types of errors are more instrumental for uncovering important task information and diagnosing task progress.

The results above suggest that specific types of errors committed at specific points in training may have had positive effects. Furthermore, it appears as though the error

training manipulations led trainees to make more errors during the early stages of each training session. These findings suggest that the role of errors in training is difficult to capture and requires detailed analyses that incorporate information about the nature of the training, the type of error that was committed, and when the error was committed.

Identification of these error patterns and their effects may serve as a next step for the current data and as a fruitful avenue of inquiry for future research designed specifically to address this issue.

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