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Error Management Training from a Resource Allocation Perspective: An Investigation of Individual Differences and the Training Components that Contribute to Transfer

by

Madeline Campbell

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APPROVED, THESIS COMMITTEE:

Margaret E. Beier, Assistant Professor, Chair Psychology

Michael J. Watkins, Professor Psychology

David M. Lane, Associate Professor Psychology, Statistics, & Management

Deborah J. Barrett, Professor Practice of Professional Communication

HOUSTON, TX

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ABSTRACT

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Error management training is an intervention that capitalizes on the cognitive benefits of making errors for transfer of training, while minimizing the negative effects of errors on motivation. This study examined the effects of the structural and instructional components of error management training within a resource allocation framework, and investigated the role of distal predictors (cognitive ability and learning goal orientation) and proximal predictors (self-regulatory processes: emotion control, metacognitive activity, and self-efficacy) on training outcomes. Participants ($N = 161$, mean age = 39.7) were recruited from the community and were trained on computer database software in one of three conditions: high structure + error encouragement instructions, high structure + no instructions, or low structure + error encouragement instructions. Training effectiveness was assessed on multiple indices of learning (task performance, knowledge structures, and self-efficacy), measured immediately following training and after a 1-week retention interval. Key findings include an age x cognitive ability x effect of instruction interaction for training performance, indicating that individual differences should be considered when designing training to optimize transfer. Low structure training was found to enhance immediate task performance for all learners, but this effect did not persist over time. In addition, emotion control fully mediated the relationship between
learning goal orientation and self-efficacy for knowledge retention in the error
couragement training conditions, as well as interacting with the effect of instruction to
predict task performance.
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INTRODUCTION

Transfer is the ultimate goal of training, and one well established technique to enhance transfer is to create difficulty during practice (Schmidt & Bjork, 1992). Designing a learning environment that induces errors makes training more challenging and has been found to improve transfer. However, increasing the difficulty of training has potential to negatively affect learner motivation and self-efficacy. Error management training is a training intervention that capitalizes on the cognitive benefits of making errors for transfer of training while minimizing the negative effects of errors on motivation (Keith & Frese, 2005). The study presented here includes the examination of both cognitive ability and motivational components that potentially contribute to learning during training. The theoretical model that frames this study is one of resource allocation.

First, cognitive approaches to training for transfer will be presented, followed by a discussion of the resource allocation framework as a perspective that integrates cognitive and motivational approaches to learning. Error management training and relevant aptitude-treatment interactions will then be reviewed, followed by a discussion of the evaluation of training effectiveness. The aims of the current study will then be outlined, followed by a description of the methods, and a discussion of the results and implications for theory and practice.

Cognitive Approaches to Training for Transfer

The primary goal of training is optimal transfer of training to the anticipated posttraining environment (Bjork, 1994). Effective transfer of training involves both maintenance and generalization; that is, imparting knowledge that persists over time and
that can be adapted to novel problems and contexts, respectively (Smith, Ford, & Kozlowski, 1997). Increasingly, as fewer jobs require rote repetition of the same task, it is this ability to flexibly apply knowledge to new problems that is the desired outcome of training (Hesketh & Ivancic, 2002).

In their influential article on transfer, Schmidt and Bjork (1992) reviewed diverse research studies on the transfer of training and highlighted a somewhat paradoxical principle: training manipulations that maximize performance during training can be detrimental to transfer; and conversely, training manipulations that are detrimental to performance during training can be beneficial for transfer. They described empirical evidence that several practice conditions hindered performance during training but optimized long-term transfer across motor, verbal, and problem-solving tasks. These practice conditions included sequencing of practice tasks, feedback schedules, and inducing variability of practice.

For example, Shea and Morgan (1979) assigned random or blocked practice schedules to participants for training on multiple complex motor tasks. Blocked practice involved sequential blocks of trials for each task, with participants completing all practice trials for one task before moving on to practice the next task. Random practice involved an identical number of trials for each task, but the order of the trials was randomized such that the same task was never practiced on two successive trials. Performance during skill acquisition was considerably better in the blocked condition, but after a 10-day retention interval, participants in the random condition outperformed those in the blocked condition, regardless of whether the test itself was random or blocked. Similarly, introducing variability into practice may impair training performance compared to
constant practice, but leads to better transfer performance. For example, Nitsch (1977; as cited in Bransford, Franks, Morris, & Stein, 1979) trained participants to recognize novel concept-words by providing several uses of the word either in a constant context (e.g., a restaurant) or a variable context (in multiple settings). When the novel word was presented in the constant context (e.g., restaurant) at test, participants in the constant practice condition were better able to identify the word, and it is likely they performed best during acquisition. However, when the word was presented in a novel context at test, participants in the variable practice condition outperformed those in the constant practice condition. In another paradigm, trainees learning a computer language (LISP) were either given feedback on their performance after every trial, or given regular feedback initially, followed by less frequent feedback in later trials (expanded spacing of feedback). Performance during skill acquisition was poorer with expanded spacing of feedback compared to feedback following every trial, but retention performance was enhanced (Schooler & Anderson, 1990).

Schmidt and Bjork (1992) concluded that the interventions that enhanced transfer, despite impairing immediate performance, all shared one characteristic: they added difficulty during the acquisition phase. These difficulties are believed to enhance transfer by prompting deeper processing during learning and by more closely matching conditions in the posttraining environment. Bjork (1994, p. 192) argued that, “in responding to the difficulties and challenges induced by such manipulations the learner is forced into more elaborate encoding processes and more substantial and varied retrieval processes.” This latter point is critical to effective transfer. When trained knowledge and behaviors are applied in the real-world, they are typically needed in a varied, spaced context without
frequent feedback, rather than in a constant, blocked context with regular feedback.

Training can rarely cover all of the variations in task and context that may occur outside the training context, but maximizing the overlap between processes used in training and in the transfer context will be the most effective approach for transfer. The importance of matching the processes involved during training and transfer has been demonstrated in studies supporting the transfer-appropriate processing principle (e.g., Morris, Bransford, & Franks, 1977). The principle of transfer-appropriate processing can be stated simply: “performance is best when processes at test [transfer] are similar to processes at study [training]” (Kelley & Lindsay, 1996, p. 43). By providing challenges to learning via task variability, random practice, and expanded spacing of feedback, a training program better equips a trainee for the processing required in the real world.

Schmidt and Bjork’s (1992) review stressed the importance of training evaluation that is based on transfer performance, rather than on performance during training. Relying on the latter as an indicator of training success may be misleading, as the true utility of a training program is evident in the long-term retention and generalization of knowledge and skills. In a training context, this problem is compounded by the fact that trainees do not like to make mistakes and often attribute their errors to poor training (Ghodsian, Bjork, & Benjamin, 1997). This “anti-error bias” means that trainees interpret high performance and a rapid rate of improvement during training as the hallmarks of effective instruction, and they interpret mistakes and a slowed improvement rate as indicators of poor training (Ghodsian et al., 1997). As training programs are frequently evaluated only by ratings of trainee satisfaction at the conclusion of training (Bjork, 1994), ineffective programs may receive better evaluations than more effective programs
that degrade immediate performance, reinforcing the use of poor training designs. In order to evaluate the effectiveness of training, Schmidt and Bjork (1992) recommend two criteria: posttraining performance following a retention interval, and performance tests requiring generalization of knowledge and skills to novel problems in a variety of contexts.

Applied researchers have echoed Schmidt and Bjork's criticism of training evaluation. Kraiger, Ford, and Salas (1993) described learning as a process that occurs over time, and recommended the inclusion of multiple cognitive, skill-based, and affective learning criteria in training evaluation. More recently, training researchers have focused on building adaptive expertise, which is defined as the "the ability to adapt to changing task demands and to invent solutions to novel problems [permitting] the solution of non-routine problems or problems outside one's domain" (Hesketh & Ivancic, 2002, p. 251). Adaptive expertise is believed to be a result of "deeper conceptual understanding of the target domain" (Smith et al., 1997, p. 93), which can itself be measured using knowledge structure assessment (e.g., Schvaneveldt, 1990). Adding difficulty during training by, for example, inducing errors during acquisition, can "engage attention and require effortful analytic processing" (Hesketh, 1997, p. 327). This "active and mindful learning during training" (Smith et al., 1997, p. 93) is regarded to be a critical factor in training for adaptive expertise.

**Integrating Cognition and Motivation in a Framework for Learning**

Cognitive approaches to learning have been very influential in shaping training design and educational techniques. Adding difficulty by manipulating practice, as
advocated by Schmidt and Bjork (1992), has been shown to result in effective transfer performance on a wide range of motor and verbal tasks. However, cognitive approaches typically fail to consider the role of motivation and individual differences in training despite a substantial body of evidence demonstrating their impact on training outcomes (e.g., Kozlowski, Gully, Brown, Salas, Smith, & Nason, 2001; Yeo & Neal, 2004). For example, adding difficulty during practice degrades training performance, which may lead to negative consequences such as decreased trainee self-efficacy and increased trainee frustration, both of which affect a trainee's willingness to remain engaged in a learning task.

Theories in applied (i.e., industrial/organizational and educational) psychology typically incorporate both motivational and cognitive processes in the examination of learning. A resource allocation perspective, for example, is a broad framework that emphasizes the limitations of our cognitive resources and focuses on the various attentional demands on our cognitive system (Kanfer & Ackerman, 1989). When learning a complex task, performance is determined by individual differences in attentional resources, the attentional requirements of the task, and the self-regulatory processes used to allocate attention across tasks (Kanfer, Ackerman, Murtha, Dugdale, & Nelson, 1994). Attentional resources are allocated according to distal and proximal influences on learning. Distal influences, including cognitive ability and dispositional tendencies such as goal orientation, determine overall attentional capacity and the proportion of total resources allocated to a task. Proximal influences, including self-regulatory processes such as metacognitive activity and emotion control, represent information-processing strategies that occur during task engagement that may facilitate or hinder learning.
(Kanfer & Ackerman, 1996). Figure 1 outlines this approach to predicting training performance. The distal predictors of cognitive ability and goal orientation operate on training outcomes via their effect on more proximal self-regulatory resources. That is, cognitive ability and goal orientation affect self-regulatory processes during learning, which, in turn, predict training performance.

*Figure 1. Distal and proximal predictors of training performance*

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**Distal Predictors of Training Performance**

*Cognitive Ability*

A primary distal predictor of learning is cognitive ability. According to the resource allocation perspective, cognitive ability is an index of our maximum attentional capacity (Kanfer & Ackerman, 1996). Cognitive ability refers to the “ability to integrate, process, and apply information” (Gully, Payne, Koles, & Whiteman, 2002, p. 150), and it has consistently been found to be a powerful predictor of training performance (Ree &
Earles, 1991). Individuals with high cognitive ability typically perform better during training, which increases their confidence in their ability to perform the trained task. As a result, cognitive ability has been found to predict posttraining task performance, declarative knowledge, and self-efficacy (Gully et al., 2002).

Learning Goal Orientation

Learning (or mastery) goal orientation is a motivationally-oriented, distal predictor of learning. It refers to the mental framework an individual uses to respond to and interpret achievement situations (Salas & Cannon-Bowers, 2001). Traditionally, learning goal orientation has been associated with an adaptive response pattern, 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” (Bell & Kozlowski, 2002, p. 498). Empirical evidence supporting these theoretical claims has been mixed, and a recent review of the training motivation literature concluded that “research on the benefit of mastery orientation in training is surprisingly sparse and equivocal” (Beier & Kanfer, in press). For example, learning goal orientation was found to be positively related to performance following training on a radar-tracking task (Bell & Kozlowski, 2002), but no beneficial effect of learning goal orientation on performance was detected on a computerized scheduling task (Steele-Johnson, Beauregard, Hoover, & Schmidt, 2000). The mixed results may be due in part to the moderation of the relationship between learning goal orientation and performance by variables such as task complexity (Steele-Johnson et al., 2000) and stage of skill acquisition (Yeo & Neal, 2004).
Within the resource allocation framework, goal orientation is a distal motivational disposition that directs proximal self-regulatory processes (Kanfer & Heggestad, 1997). For example, Schmidt and Ford (2003) found a strong positive association between learning goal orientation and metacognitive activity, with metacognitive activity partially mediating the relationship between goal orientation and learning outcomes in web-design training. In addition, it is plausible that certain behavioral components of learning goal orientation, such as persistence in the face of failure, may also be associated with self-regulatory mechanisms such as emotion control, discussed below.

**Proximal Predictors of Training Performance**

Proximal predictors of learning are the “volitional processes by which intentions are translated into performance” (Kanfer & Ackerman, 1996, p. 155). These self-regulatory processes occur during task engagement (rather than preceding it) and act as mediators between distal predictors and training outcomes (see Figure 1).

Self-regulation is defined as “processes that enable an individual to guide his or her goal-directed activities over time and across changing circumstances, including the modulation of thought, affect, and behavior” (Porath & Bateman, 2006, p. 185). This general definition captures three interdependent facets of self-regulation that are critical in a training context, namely emotion control, self-efficacy, and metacognition. Each will be discussed in turn.

*Emotion Control*

Emotion control involves “the use of self-regulatory processes to keep performance anxiety and other negative emotional reactions (e.g., worry) at bay during
task engagement" (Kanfer, Ackerman, & Heggestad, 1996, p. 186-187). Emotion control strategies enhance performance by inhibiting emotional states that may undermine engagement in a task. Emotion control is an important self-regulatory skill for learning, particularly early in learning when trainees typically make many errors (Kanfer & Ackerman, 1996; Keith & Frese, 2005). Failures in emotion control direct attention towards the self and divert resources away from the task, resulting in worry, evaluation apprehension, and poorer performance. For example, trainees who performed poorly on an air-traffic control simulation reported more frequent negative emotions than higher-performing trainees: they thought more about doing worse than others, experienced dissatisfaction and feelings of unhappiness, and reported more self-directed anger at making mistakes (Kanfer & Ackerman, 1996).

Metacognition

Metacognition is a self-regulatory process that encompasses the regulation of thoughts and behaviors. It was originally defined as an individual’s knowledge of and control over their cognitions (Flavell, 1979), but has since been used to refer to both self-awareness of one’s knowledge and the adoption of self-regulatory skills, such as planning, monitoring, and updating goal-appropriate behavior (Ford, Smith, Weissbein, Gully, & Salas, 1998). The specific consequences of metacognition on attention are unclear: the monitoring of performance relative to goals may be automatic, even on complex tasks, but engaging in strategies to meet goals may be more resource-dependent (DeShon, Brown, & Greenis, 1996). However, training research suggests that metacognitive skills are beneficial for learning, perhaps because they increase the efficiency of attention use by directing resources where they are needed most. Trainees
with greater metacognitive skills have been found to learn more effectively because they monitor their progress against their goals, identify when they are experiencing problems, and adjust their learning behaviors to meet their goals (Ford et al., 1998). Numerous studies have demonstrated the beneficial effects of metacognitive activity on academic performance (e.g., Campbell & Beier, 2006; Pintrich & DeGroot, 1990), and on training performance and self-efficacy (e.g., Ford et al., 1998; Schmidt & Ford, 2003).

When, as a result of metacognitive monitoring of performance, an individual notices a discrepancy between their goal and their performance, they will increase effort exertion if they believe they are capable of achieving their goal (Kanfer & Ackerman, 1989). This belief in one’s ability to perform a specific task is termed self-efficacy, and this third proximal predictor will be discussed next.

**Self-efficacy**

Self-efficacy has been defined as the “belief in one’s capabilities to organize and execute the courses of action required to produce given attainments” (Bandura, 1997, p. 3). It influences an individual’s choice of activities, effort expended, and persistence (Bandura, 1977), and has been shown to be an important predictor of training performance in numerous studies (e.g., Ford, et al., 1998; Kozlowski, et al. 2001; Martocchio & Judge, 1997). Self-efficacy beliefs have been found to directly influence motivation that is manifested in the amount of on-task effort (Martocchio, 1994); that is, individuals with high levels of self-efficacy exert greater effort in training than those with low levels of self-efficacy as they possess a belief in their ability to master the task (Bandura, 1991). Consistent with its representation here as a proximal predictor of learning outcomes, self-efficacy may also play a more complex role in training
performance by mediating the relationship between distal individual difference variables and learning. For example, in an academic setting, the relationship between cognitive ability and exam performance was partially mediated by task-specific self-efficacy (Chen, Gully, Whiteman, & Kilcullen, 2000), although other studies report that this mediation occurs only with simple tasks, not with complex tasks (Chen, Casper, & Cortina, 2001). Furthermore, learning goal orientation has been found to correlate positively with self-efficacy, which is, in turn, related to performance in undergraduate course exams (Phillips & Gully, 1997). This is suggestive of a mediating role of self-efficacy between distal goal orientation and learning outcomes. However, there is some controversy over the causal direction in the self-efficacy – performance relationship. Vancouver, Thompson, and Williams (2001) trained participants on an analytic game with frequent feedback on performance. Although they found the widely-reported positive correlation between self-efficacy and performance in a between-person analysis, they found a negative correlation between self-efficacy and subsequent performance with a within-person/over time analysis. The authors suggested that the typical positive relationship may be primarily an effect of past performance on self-efficacy, and that self-efficacy can have a negative effect on subsequent performance by rendering a person complacent. That is, high self-efficacy may result in trainees being overly confident in their abilities, and this “complacent self-assurance undermined motivation to adversely affect a person’s performance across time” (Vancouver et al., 2001, p. 611).

It should also be noted that self-efficacy may be conceptualized as both a predictor of performance and as a training outcome (Kraiger et al., 1993). Thus far, it has been described as a proximal predictor but, consistent with the notion that learning should
be evaluated on affective, as well as cognitive, training outcomes, this study also measured self-efficacy as a criterion.

**Error Management Training**

One training manipulation that has attempted to integrate knowledge from cognitive theories of learning and motivational approaches to training is error management training. This technique utilizes the effectiveness of effortful learning to increase transfer, as well as promoting self-regulatory processes during learning (Keith & Frese, 2005). More specifically, error management training introduces difficulty during practice by creating training environments that induce errors, whilst reassuring trainees that errors are beneficial for learning and are a natural part of the learning process.

Historically, errors have been regarded as detrimental from both a motivational and information processing perspective (Ivancic & Hesketh, 1995). Some early learning theorists believed that incorrect responses interfered with the learning of correct responses, and must be unlearned before correct responses could be learned (Skinner, 1968). In addition, errors were considered to be aversive stimuli that could inhibit responding, therefore highly structured training programs were designed to encourage errorless learning (Mory, 1992). In support of this approach, studies have shown that errors are indeed often accompanied by feelings of stress and frustration, with emotional strain rising as the time required to handle the error increased (Brodbeck, Zapf, Prumper, & Frese, 1993); and there is some evidence that errorless training is more efficient, with shorter training times in computer-based training (Carroll & Carrithers, 1984; Carroll & Kay, 1985). However, a growing body of evidence suggests that errors serve an essential
role in learning. Errors may provide informative feedback (Lorenzet, Salas, & Tannenbaum, 2005) and disrupt premature automatization of actions (Frese, 1995). Training under conditions designed to elicit errors was found to encourage exploratory behavior and development of new knowledge (Dormann & Frese, 1994), stimulate metacognitive activity (Keith & Frese, 2005), and promote effective strategy development (Ivancic & Hesketh, 2000).

Error management training is a relatively new training intervention that has attempted to harness the cognitive benefits of incorporating errors into training, while minimizing the negative effects of errors on motivation and self-efficacy (Nordstom, Wendland, & Williams, 1998). Error management training involves explicitly allowing trainees to make errors, and encouraging trainees to regard errors positively as an informative source of feedback. Training is designed such that trainees will inevitably make mistakes, but they are repeatedly reminded of the benefits of errors in order to reduce the frustration that accompanies them (Frese, 1995). Error management training is typically compared to a more conventional step-by-step training method (termed error avoidant), whereby trainees are given detailed instructions to complete the training tasks, limiting their opportunities for errors (e.g., Heimbeck, Frese, Sonnentag, & Keith, 2003). In line with other research that adds difficulty during training (e.g., Schmidt & Bjork, 1992), training performance itself may be poorer in the error management condition compared to the error avoidant condition in terms of number of errors committed, but participants in the error management training condition typically demonstrate superior performance on difficult or adaptive transfer tests (e.g., Keith & Frese, 2005).
Heimbeck et al. (2003) employed an error management training paradigm in computer software training (Microsoft Excel). They compared performance following training in three between-subjects training conditions: error-avoidant, error training with no instructions, and error training with error management instructions. During training, the error-avoidant group was given detailed, step-by-step instructions to complete the practice tasks without error. The error training group was given only very basic information on how to complete the practice tasks in a ‘minimal manual’, increasing the probability that they would make mistakes during training. The error training with error management instructions group received the same minimal manual as the error training group, but in addition they were repeatedly informed that errors are beneficial and are a natural part of the learning process. In a subsequent test, trainees in the error training with error management instructions condition performed better than those in the error-avoidant and error training (with no instructions) conditions on transfer tasks, particularly on more difficult tasks. The authors concluded that it was the combination of error occurrence and instructions to minimize negative reactions to errors that was crucial for superior test and transfer performance, not error occurrence alone. The effect was substantial: Heimbeck et al. (2003) reported medium to large effect sizes ranging from Cohen’s $d = 0.63$ to 0.90 for the difference in task performance between error-avoidant and error training with error management instructions conditions, controlling for computer experience. In another study, Keith and Frese (2005) reported a Cohen’s $d$ of 0.75 for the difference in adaptive transfer performance between error-avoidant and error training with error management instructions conditions on the presentation software Microsoft Powerpoint, again controlling for computer experience.
Further research on error management training has revealed two important self-regulatory mediators of the performance effects of this intervention: emotion control and metacognition. Keith and Frese (2005) found that emotion control and metacognitive activity independently mediated the effect of training condition on adaptive transfer performance. They argued that error management training allowed participants to develop and practice emotion control skills during training, as errors were framed positively and participants were encouraged to use errors as learning experiences. When faced with the challenges of novel test problems, participants in the error management condition were able to reappraise negative emotions and remain focused on the task. In contrast, participants in the error avoidant condition were not given any instructions on how to handle errors, and were prevented from making mistakes during training. The authors suggested that, at test, the error avoidant group were unprepared to control the frustrations they experienced, and that these negative emotions had a detrimental effect on their performance.

Keith and Frese (2005) also reported that participants in the error management training condition engaged in more metacognitive activity (as measured by a think-aloud protocol), which boosted their performance. Metacognition has a critical role in error management training. It is particularly important in learning contexts with little structure or guidance, as in the error management condition, where trainees take more responsibility for their own learning (Schmidt & Ford, 2003). When trainees make errors, they create a discrepancy between their expectations and reality that must be explained (Ellis & Davidi, 2005). Errors draw attention sharply to the task, and encourage trainees to generate and test hypotheses regarding the cause of the error and potential solutions, as
well as evaluate the outcome of their solutions (Ivancic & Hesketh, 2000). These metacognitive strategies are believed to highlight incorrect assumptions in trainee understanding and enable the integration of new information with existing knowledge (Smith, Ford, & Kozlowski, 1997), which is presumed to result in the development of richer, more elaborate mental models (Heimbeck et al., 2003; Lorenzet et al., 2005). This assumption is supported by the superior retention of trained material and transfer to novel problems in the error management condition (Heimbeck et al., 2003). Participants in the error avoidant condition do not need to engage in these metacognitive behaviors as there are no opportunities to make errors.

In summary, error management training is effective because it incorporates the cognitive benefits of errors and promotes metacognitive activity, while minimizing negative emotional thoughts. From a resource allocation perspective, errors draw attention to the task and encourage the self-regulatory process of metacognition, while the positive framing of errors prevents attention being diverted to off-task and self-referent thoughts or to performance anxiety.

From an applied perspective, error management training is particularly beneficial because, in addition to enhancing transfer, it prepares trainees for the errors they will encounter when they return to the workplace. Errors are inevitable, and a training program cannot typically train for every variation in the task and context, therefore it is imperative to train individuals to cope with errors effectively outside of the training context (Brodbeck et al., 1993). Facilitating an exploratory approach and the development of strategies to deal with errors during training may help trainees to adopt
the same approach when faced with novel problems in an actual work situation (Frese, 1995).

**Error Management Training & Aptitude-Treatment Interactions**

Cognitive ability is an index of our attentional capacity (Kanfer & Ackerman, 1996), and different training conditions place various attentional demands on this limited capacity. Therefore, individual differences in cognitive ability can influence the effectiveness of various training designs, such that designs well suited to the attentional capacity of high ability trainees may be too challenging for low ability trainees. This is an example of an aptitude-treatment interaction. An aptitude-treatment interaction occurs when an ability (e.g., cognitive ability) or attribute (e.g., learning goal orientation) interacts with an instructional treatment (Snow, 1989); that is, performance following a particular training manipulation will differ depending on an individual’s level on an aptitude or attribute.

Researchers have begun to investigate aptitude-treatment interactions within the error management training paradigm. The interactive effect of cognitive ability and training condition on performance has been explored using error management instructions, but without the structural manipulation used by Heimbeck et al. (2003). Gully et al. (2002) measured cognitive ability and then trained participants on a radar-tracking and decision-making task (TEAMS/TANDEM). All trainees received identical treatment with respect to training design, content, materials, and timing. The only difference in the training conditions was in the instructions given to trainees. The error encouragement group was advised of the positive function of errors for learning and was
told that making mistakes was common and to be expected. The error avoidant group was
told that errors are detrimental to effective learning, and that they should be avoided. The
control group was simply told to try their best. Gully et al. (2002) found that high ability
trainees performed best and reported higher self-efficacy with error encouragement
instructions, whereas low ability trainees performed best and reported higher self-efficacy
with error avoidant instructions. The authors suggested that high ability trainees were
better able to diagnose and learn from their errors, and therefore reaped the cognitive and
motivational benefits of error-training. From a resource allocation perspective, it could be
argued that a larger proportion of the cognitive resources of high ability trainees were
free to diagnose errors and engage in hypothesis-testing, as the task demands did not
over-extend their attentional resources. However, for low ability trainees, the complex
task absorbed a considerable proportion of their cognitive resources (which were already
more limited than those of high ability trainees), leaving little capacity for error diagnosis
and interpretation.

It is important to consider the ability level of trainees when designing a training
intervention, as ability will partially determine how well they cope with the cognitive
demands of the task. One important dimension of training design that influences task
demands is structure. Although widely used to classify training designs, structure has not
been clearly defined in the training literature. High structure typically describes training
that has low learner control. Low learner control is defined as little or no “opportunity to
select the method, timing, practice, or feedback” (Ford et al., 1998, p. 219). Trainees in
high structure conditions have little choice regarding the content or sequence of learning
(Smith et al., 1997), and may receive high levels of external guidance in the form of step-
by-step instructions, organizers, and direction to progress in a particular sequence. Low structure typically describes training that involves exploratory learning, in which trainees are free to work in a learning environment with little or no guidance (Mayer, 2004), has high learner control, or has a degree of incompleteness of instruction. Under low structure conditions, trainees are required to select what to learn and in what order, how much to practice, how to integrate new information with existing knowledge, and which learning strategies to adopt. Training that is high in structure is less cognitively demanding than training that is low in structure, but it is less conducive to trainees imposing their own structure on the content.

Studies on the interaction between cognitive ability and training structure on task performance have confirmed this notion by assessing trainee ability and testing performance following training conditions that vary in structure. Trainees low in cognitive ability typically perform better following high structure training, whereas trainees high in cognitive ability typically perform better following low structure training (Cronbach & Snow, 1977; Snow, 1989). Low ability trainees have fewer cognitive resources overall, and training can place high demands on their limited attentional resources. This attentional drain may leave few resources available to devote to structuring their own learning, therefore performance is best when structure is provided in training. High ability trainees, however, have sufficient resources to deal with the cognitive demands of low structure training. In addition, they generally express a bias against high structure, which can interfere with their own learning strategies and preferences (Snow, 1989).
These findings have far-reaching implications for contemporary training design. It has been widely noted that demographic shifts in the workplace have increased training needs for older learners. The Bureau of Labor Statistics (2002) estimated that almost half of the U.S. workforce will be aged 45 or older by 2010, and rapid changes in job requirements and emerging new technology mean that workers must retrain regularly (Charness, Kelley, Bosman, & Mottram, 2001). Despite the increasing need for research on the most effective training designs for older workers, relevant research is sparse since most studies are conducted on college students. One of the most frequently cited differences between older learners and the typical research sample of college students relates to cognitive ability. The fluid components of cognitive ability (e.g., abstract reasoning and working memory), which are crucial in the training of complex tasks, peak in early adulthood and then decline with age (Horn & Cattell, 1967). These changes in ability have been found to influence the success of training interventions. In one particularly relevant study, Sanders, Gonzalez, Murphy, Pesta, and Bucur (2002) compared the performance of younger and older adults following high-variability and low-variability training on a mental arithmetic algorithm. Consistent with Schmidt and Bjork’s (1992) notion that increasing training difficulty impairs immediate performance, they found better performance during low-variability training in both younger and older adults. They also found the expected benefit of high-variability training on transfer performance, but only for the younger adults. No transfer performance differences were detected between older adults in the high- and low-variability conditions. Performance on the mental arithmetic task used in this study is highly predicated on working memory, a component of fluid ability (Campbell & Charness, 1990), and the authors suggested that
there was an “agreeable fit between the working memory characteristics of the younger learners and the demands imposed by the high-variability training condition that did not exist for the older learners” (Sanders et al., 2002, p. 172).

Furthermore, Ackerman and Beier (2006) found that fluid abilities were related to learning for an unstructured training task, suggesting that adult learners may perform best with highly structured training, as it may ameliorate the negative effects of declines in abilities associated with learning. Error management training is low in structure, and it places high demands on trainees in terms of processing new information and abstract problem-solving, therefore performance may be highly predicated on cognitive ability. If, on average, older learners have fewer resources to devote to training, then error management training may be less effective for this population.

These findings suggest that there are important aptitude-treatment interactions that must be considered when designing training interventions. In order to generate predictions regarding the potential effects of aptitude-treatment interactions in error management training, a closer investigation of the structural and instructional components of this intervention is warranted. Heimbeck et al. (2003) compared performance following three training conditions: error avoidant, error training with no instructions, and error training with error management instructions. These conditions varied on two dimensions: structure and instruction. The error avoidant group received highly structured training, with explicit, step-by-step guidance on how to complete the training tasks successfully, but they received no instructions regarding errors. The error training group received relatively unstructured training, with only basic information on the software, and no instructions regarding how to deal with errors. The error training
plus error management instructions group received the same relatively unstructured training, with instructions relating to effective error management. Therefore, Heimbeck et al. (2003) compared three cells in a 2 (structure) x 2 (instructions) design. They did not assess the performance of the fourth cell: high structure with error management instructions. Presumably, the authors would argue that providing error management instructions to a group who are unlikely to commit errors is nonsensical. However, it is conceivable that instructions that encourage and positively frame errors during training could improve performance, regardless of structure. In particular, learners who have lower self-efficacy for computer training may benefit from the reassurance that making errors is not only acceptable, but beneficial for learning.

Heimbeck et al.'s (2003) results suggest that it is the error encouragement component of error management training that is crucial. They reported significantly enhanced performance in the low structure error training with error management instructions group, but no difference between performance in the high structure error avoidant group and the low structure error training with no error management instructions group. They concluded that it was not the structure of the task alone, but the combination of low structure with error management instructions that resulted in superior performance. However, they used only a college student sample, who are presumably relatively high in cognitive ability compared to the general working population, and more accustomed to learning environments. It is possible that these results would not generalize to all learners, across age, ability, and level of self-efficacy. Indeed, even within a college sample, Gully et al. (2002) found that error encouragement instructions were beneficial only for high ability trainees.
Following Gully et al.'s (2002) call for research into other individual difference variables that may affect training performance, Heimbeck et al. (2003) explored a second aptitude-treatment interaction within the error management training paradigm: goal orientation. They hypothesized that error management training would be particularly beneficial for trainees high in learning goal orientation, as they possess a tendency to pursue challenging tasks, view errors as learning opportunities, and persist when faced with failure. This dispositional approach to learning situations corresponds with the goals of error management training: to add difficulty during training by inducing errors, while maintaining motivation to learn via emotion control. Somewhat surprisingly, Heimbeck et al. (2003) found no effect of learning goal orientation, and suggested their null effect was due to the error management training representing a ‘strong’ situation (Mischel, 1968). In other words, they proposed that in their study, the error management training created a context that left little room for the expression of personality variables.

**Evaluation of Error Management Training**

Training research has been criticized for being overly simplistic in its approach to evaluating learning and learning outcomes (e.g., Holton, 1996). In response, Kraiger et al. (1993) recommended that training evaluation research be driven by a theoretically based model that regards learning outcomes as multidimensional. They presented a framework that outlined cognitive, skill-based, and affective outcomes of learning, and emphasized learning as a process which occurs over time. Cognitive outcomes include declarative knowledge and knowledge organization; skill-based outcomes include task performance and adaptive transfer; and affective outcomes include self-efficacy and attitude change.
Error management training research typically measures only task performance, although some studies have also assessed declarative knowledge (e.g., via multiple-choice tests) and self-efficacy. Interestingly, although many researchers claim that error training results in the development of richer knowledge structures, none have actually measured knowledge organization (Ellis & Davidi, 2005; Frese, 1995; Heimbeck et al., 2003; Lorenzet et al., 2005). Knowledge structures - also known as mental models, schemata, and cognitive maps - are representations of the organization of knowledge in a domain, obtained by measuring the interrelation of concepts, ideas, and rules within that domain (Davis, Curtis, & Tschetter, 2003). During instruction, trainees are taught both declarative knowledge and, more tacitly, about the associations between concepts (Goldsmith & Kraiger, 1997). They begin to develop an increasingly organized, meaningful, and accurate knowledge structure, which reflects their understanding of the domain and allows them to retrieve and generalize their knowledge. Given that this transfer of learning is the primary goal of training, knowledge structures are emerging as a promising index of conceptual understanding. Through training, it is hoped that an individual's knowledge structure will more closely resemble the actual structure of that domain, or from a measurement perspective, the knowledge structure of a domain expert.

Multiple methods exist to measure knowledge structures, but many suffer from their reliance on participants possessing conscious access to their mental processes and structures. A more sophisticated alternative involves inputting numeric ratings of relatedness between concepts in a domain into a network scaling algorithm to elicit the latent knowledge structure. Pathfinder (Schvaneveldt, 1990) is one such method. It converts concept relatedness judgments into a graphical representation of a knowledge
structure, and produces a quantitative index of the similarity between two structures. In Pathfinder, each concept in a domain is represented as a node in a network, and each link between nodes has a weight, determined by the distance between the two concepts. Pathfinder first links all of the concepts by assigning a weight to each link in the network. The Pathfinder algorithm then systematically removes direct links if there is a shorter indirect route between two concepts. The resulting network represents the psychological proximity of concepts. The similarity between an expert and a trainee knowledge structure is a useful indicator of learning, and scores can range from zero to one, where zero means the networks share no links, and one means the networks are identical. Typical similarity to expert values include .16 for brief and poorly-structured training and .23 for brief but well-structured training on a naval radar task simulation (TANDEM; Kraiger, Salas, & Cannon-Bowers, 1995), and around .3 following fairly extensive training on Space Fortress (Day, Arthur, & Gettman, 2001).

Previous research using Pathfinder to assess learning has found that students’ knowledge structures become more similar to that of an expert over a course of instruction (Campbell & Beier, 2006; Goldsmith & Johnson, 1990). Pathfinder has also successfully captured meaningful differences between expert and novice fighter pilots (Schvaneveldt, Durso, Goldsmith, Breen, Cooke, Tucker, & de Maio, 1985), predicted skill retention and skill transfer in trainees learning a complex video game (Day et al., 2001), predicted exam performance in a college level class (Goldsmith, Johnson, & Acton, 1991), and predicted individual differences in performance self-efficacy (Davis et al., 2003).
Task-relevant self-efficacy is another important learning outcome. Although self-efficacy is often measured as a predictor of performance or a mediating self-regulatory process, it can also be regarded as a criterion. According to Bandura (1977), training changes behavior in part by generating and boosting self-efficacy, therefore increases in self-efficacy may be an indication of learning. Enhancing self-efficacy may even be an intended objective of the training, as research suggests that posttraining self-efficacy may determine whether trainees apply their new skills (Bandura, 1983) and whether long-term transfer of training occurs (Kraiger & Salas, 1992; as cited in Kraiger et al., 1993). Error management training is designed to prevent reductions in self-efficacy that may result from frequently making mistakes. Typically, error-prone performance would lower self-efficacy, as trainees would interpret their mistakes as evidence of an inability to successfully perform a task. However, the error management instructions positively reframe errors and attempt to convince trainees that mistakes are a natural part of the learning process, rather than evidence of failure. Self-efficacy is dynamic and is updated in light of recent performance (Vancouver et al., 2001), therefore researchers are beginning to measure changes in self-efficacy over time, particularly in response to feedback on performance (Yeo & Neal, 2006). Evidence from error-free training studies suggests that high structure conditions may falsely inflate self-efficacy, as the success guaranteed by step-by-step instructions may lead participants to overestimate their skill level (Lorenzet et al., 2005). Lorenzet et al. (2005) reported that participants in high structure training conditions experienced a drop in self-efficacy following a performance test that highlighted the inaccuracy of their initial judgment.
Given that transfer is the goal of training, assessing maintenance of learning over time and generalization across contexts is critical to effective training evaluation (Schmidt & Bjork, 1992). Since there are often long periods of time between training and the application of new knowledge, transfer should be evaluated after a temporal delay, where possible. This is particularly important when assessing the effectiveness of training interventions that add difficulty during training, as the benefits of such manipulations may not be evident during immediate performance (Hesketh & Ivancic, 2002). Transfer of knowledge and skills may be evaluated by analogical transfer tasks and by adaptive transfer tasks. Analogical transfer refers to using knowledge to solve problems that are familiar or analogical to the problems faced during training (Keith & Frese, 2005). Adaptive transfer involves "using one's existing knowledge base to change a learned procedure, or to generate a solution to a completely new problem" (Ivancic & Hesketh, 2000, p. 168). When engaging in the latter type of transfer, a trainee adapts or generalizes their knowledge, perhaps by extrapolating general rules or principles, and applies it in a way that has not been directly trained. Adaptive transfer is the ultimate goal of training, as trainees cannot feasibly be exposed to every problem variation they will encounter outside of the training context, and many jobs require this flexible application of knowledge to new problems (Hesketh & Ivancic, 2002). Studies on error management training typically find a beneficial effect of the manipulation on adaptive or difficult tasks, but not analogical or easy tasks (Heimbeck et al., 2003; Keith & Frese, 2005), and the facilitation in performance compared to error avoidant training is stable over time (Heimbeck et al., 2003).
THE CURRENT STUDY

The current study evaluated the effectiveness of error management training as a design intervention within an integrated framework of cognitive and motivational variables. This study contributes to the existent literature in four distinct ways.

First, there is a need for greater clarity regarding the effects of the components of error management training. There are at least two important characteristics of error management training: (1) decreasing the structure of the learning environment such that learners can make mistakes, and (2) providing instructions that extol the benefits of making errors for learning. However, much research in this area does not separate these components (Chillarege, Nordstrom, & Williams, 2003), or tests only one of them (Gully et al., 2002). Previous research that examined both the structural and instructional components associated with error management training has tested three conditions: low structure + error encouragement instructions, low structure + no instructions, and high structure + no instructions. No studies have tested a high structure + error encouragement instructions condition. The current study tested the effectiveness of this combination of structure and instruction, as well as low structure + error encouragement instructions and high structure + no instructions conditions, on training outcomes.

Second, this study investigated individual differences in the effect of training structure and instruction that had not been explored in previous research on error management training. Given the findings on aptitude-treatment interactions relating to cognitive ability and training structure (Snow, 1989), and the relationship between cognitive ability and age (Schaie, 1996), the potential moderating effects of cognitive ability and age on training outcomes were explored. Training with low structure places
more cognitive demands on the learner, who must engage in error diagnosis and hypothesis generation and testing. Trainees with lower levels of cognitive ability have fewer resources at their disposal, therefore these trainees may have insufficient attentional resources available to learn a new complex task effectively under low structure conditions. On average, older learners have fewer cognitive resources to devote to novel problem-solving and abstract reasoning (fluid ability), which may be detrimental to learning in low structure conditions (Ackerman & Beier, 2006).

In addition, older learners may benefit from the error encouragement instructions, even in high structure conditions. Error encouragement instructions create a learning environment with a focus on learning, rather than on performance, in which errors are welcomed and less likely to divert attention away from the task. In support of this notion, Birdi and Zapf (1997) reported evidence that older workers showed stronger negative emotional reactions to errors in computer work, compared to younger workers. Typically in training studies, there is a main effect of age such that older trainees perform more poorly than younger trainees (e.g., Charness, Schumann, & Boritz, 1992; Gist, Rosen, & Schwoerer, 1988). If the effects of negative emotional reactions to errors could be ameliorated by error encouragement instructions during training, then performance of older trainees may be enhanced. The potential moderating effects of learning goal orientation on the effects of structure and instruction were also explored. Error encouragement instructions focus on the process of learning and promote the use of errors as learning opportunities, and low structure training provides the opportunity to make errors, both of which match the dispositional tendency of individuals high in learning goal orientation.
Third, the current study is potentially more generalizable to a working population, with respect to the sample and the training task, than many other training studies. The current sample included participants across ages associated with the working years, rather than college undergraduates. Cognitive ability, a major predictor of training performance, begins to decline in the early twenties; therefore training designs that enhance learning for college students may not be optimal for older trainees. Given the demographic shifts in the workforce and the rapid development of new technology, understanding the training needs of older learners should be of paramount importance to training researchers and to organizations. In addition, training researchers frequently train participants on tasks that have little ecological validity for the majority of organizations, such as radar-tracking (Gully et al., 2002; Kozlowski & Bell, 2006) and air-traffic control simulators (Kanfer & Ackerman, 1989; Yeo & Neal, 2004). The current study trained participants on database software: a domain that is more relevant to organizational training.

Fourth, the current study evaluated the training using multiple indices of learning, including cognitive, affective, and skill-based assessments. Cognitive learning was assessed using knowledge structures, as measured by Pathfinder networks; affective learning was assessed by self-efficacy, as measured by a self-report scale; and skill-based learning was assessed by task performance, measured by performance on Access problems. Tests of task performance were designed to include a substantial adaptive component, in order to measure generalization transfer. These adaptive components required participants to use new functions that had not been directly trained, or to build on their training to solve novel problems. In addition, skill-based performance was
measured over time, with assessments immediately following training (\textit{immediate}) and after a 1-week retention interval (\textit{delayed}). This enabled evaluation of maintenance transfer.

The current study investigated the efficacy of the structural and instructional components of error management training using three conditions: low structure + error encouragement instructions, high structure + no instructions, and high structure + error encouragement instructions. The fourth combination of components (low structure + no instructions) was not tested in this community sample. In a sample with a large range of ability, there was a risk that the minimal level of guidance offered in the low structure training, in combination with an absence of instructions that normalize and encourage errors, would be stressful for the participants. In addition, pilot testing with working adults suggested the error encouragement instructions were important in reducing frustration in low structure training.

Given the range of ages and ability levels in the current sample, an investigation of the previously untested combination of components (high structure + error encouragement instructions) was of greater interest. Previous research has reported greater negative emotional reactions to errors in older learners (Birdi & Zapf, 1997), as well as indicating the potential for performance improvements with high structure training (Ackerman & Beier, 2006). These findings suggest that there may be performance benefits for older learners when training is highly structured and counteracts the negative emotional effects of errors. Similarly, trainees with low cognitive ability may benefit from the high structure + error encouragement instructions condition, as this would place fewer demands on their attentional resources.
The low structure + error encouragement instructions training was expected to benefit trainees with high cognitive ability as well as trainees high in learning goal orientation. Trainees with high cognitive ability possess the attentional resources to process the training effectively and to impose their own structure on the material. Trainees high in learning goal orientation have dispositional tendencies, such as persistence in the face of failure and a desire to master new skills, that correspond with the learning approach required in the low structure + error encouragement instructions condition.

Since transfer is the goal of training, the persistence of any differential effects of structure and instruction after a retention interval are of particular interest. Therefore, skill-based performance was assessed immediately after training, and following a retention interval.

In addition, this study aimed to further theoretical understanding of the mechanisms involved in error management training. The hypothesized role of self-regulatory processes as mediators of the relationships between cognitive ability and learning goal orientation with training outcomes was investigated.
METHOD

This study evaluated the effectiveness of the structural and instructional components of error management, on multiple criteria, across different levels of ability, age, and goal orientation. Participants completed three stages of the study: a series of scales administered via the internet, a lab-based training session followed by immediate tests, and a lab-based follow-up session of tests.

Participants

One hundred and seventy-three participants between the ages of 20 and 66 were recruited from the community via newspaper advertisements, local websites, posters, word-of-mouth referrals, and employment agencies. Participants were paid $50 in return for up to five hours of their time. Participants were initially screened through a brief telephone interview. The eligibility requirements to participate in this study were as follows: (1) never used Microsoft Access; (2) no experience with other database software (e.g., Filemaker Pro) beyond the novice level; (3) native English speaker (defined as having English as their primary language since age 5); (4) normal-to-corrected vision, hearing, and motor coordination; (5) use a computer at home or work; (6) have an email address and internet access; and (7) have graduated from high school or have a General Equivalency Diploma. This study aimed to generalize the results to a working population, and eligibility criteria were set to reflect this goal. Table 1 presents the demographic characteristics of the sample.

Six participants did not complete the study since they did not return for the follow-up tests, or they withdrew during the training or immediate test session. In
addition, six participants were unable to complete the training and immediate test session because of insufficient computer skills (e.g., they were unfamiliar with basic computer functions such as operating a mouse and using the shift key to type symbols). The data from these 12 participants were dropped from the analyses. Data from the remaining 161 participants were included in the analyses. Of these 161 participants, 90 were female (55.9%), and the mean age across gender was 39.7 (SD = 13.4).

Table 1. Demographic characteristics of sample

<table>
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<th>Men</th>
<th>Women</th>
<th>Total</th>
<th>%Total</th>
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Highest level of education attained

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<th>Total</th>
<th>%Total</th>
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</table>

Procedure

The study procedure is outlined in Figure 2. Before coming into the lab, participants completed several scales online via Survey Monkey (a web-based survey administration service), including demographic information, computer experience, and
Figure 2. Outline of experiment

Stage 1: Online Scales
- Demographic information
- Computer experience
- Learning goal orientation

Stage 2: Lab Training & Tests
- Cognitive ability test
- Self-efficacy for computer training
- Training presentation & practice tasks (structural and instructional manipulations)
- Manipulation checks
- Emotion control
- Metacognitive activity
- Self-efficacy for Access test
- Task performance
- Attitude towards training

Stage 3: Follow-up Tests
- Task performance
- Knowledge structure assessment
- Self-efficacy for Access retention
- Attitude towards training

1-week delay
goal orientation. The pre-lab session was designed to take approximately 15 min. In the first lab session, participants were assigned to one of the three training conditions. First, they completed a test of cognitive ability and a self-report scale of self-efficacy for the Access computer training. The training session then started, and participants watched the training presentation, which stopped five times to allow them to complete two orienting tasks (followed by a 3 min break) and five practice tasks. Following the training session, participants completed scales measuring emotion control, error orientation, and metacognitive activity, as well as a manipulation check. After a further 5 min break, participants reported their self-efficacy for an Access test and completed the immediate task performance test in Access, followed by the attitude towards training scale. The first lab session took approximately 3.5 hr in total.

Participants returned to the lab one week later to complete the follow-up session. In the follow-up session, participants first completed the delayed task performance tests, followed by a knowledge structure assessment, and a scale measuring self-efficacy for retention of Access knowledge. Finally, they completed the attitude towards training scale. The follow-up session took approximately 1 hr 15 min. Participants were then thanked, paid, and debriefed.

Design

This study compared training performance in a between-subjects design. Participants were trained on Microsoft Access (a database software program) in one of three conditions: high structure + error encouragement instructions, high structure + no

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1 Additional scales were completed, as part of a larger study, that are not reported here.
instructions, or low structure + error encouragement instructions. The only difference between groups was during training; all tests and measures were identical for all groups.

All participants watched the same audio-visual powerpoint presentation on Access that was designed for this study. Training practice tasks were integrated in the training presentation, such that the presentation stopped after covering a new topic and participants were asked to complete a relevant practice task. The manipulations occurred only during the practice tasks.

Structure was manipulated using the information provided to participants to help them complete each practice task. In the high structure conditions, participants were given the problem and guided through each practice task with step-by-step instructions and multiple screen-shots clearly showing how to complete the task correctly. In the low structure condition, participants were given the same problem and shown a single screen-shot of the final results, but not the design or steps required to achieve them. All participants also received a brief help manual, with basic information on how to perform tasks in Access (e.g., run a query). In practice, participants in the high structure conditions appeared to use the manual very little, if at all, as they were given full directions to complete each task. Participants in the low structure condition appeared to rely more heavily on the help manual.

Instructions were manipulated via audio-visual presentation. Prior to each practice task, participants in the error encouragement conditions (but not in the no instructions condition) were reminded that errors were expected and encouraged. Following Heimbeck et al. (2003), these instructions were operationalized with statements presented on screen (which were also heard through headphones) such as “Errors are beneficial for
learning!” and “The more errors you make, the more you learn!” These statements were also prominently displayed on posters close to the computer screen, and were clearly visible to participants. In addition, initial instructions at the start of the experiment stated the benefits of errors to participants in the error-encouragement conditions. Participants in the no instructions conditions were given no additional information.

An experimenter was present during the training to ensure that participants behaved in accordance with the instructions for their condition. For example, they checked that participants in the high structure condition followed the step-by-step instructions and did not engage in error-prone exploratory learning. Participants were advised that the experimenters could not show them how to complete the practice tasks. If participants asked the experimenter questions about the tasks, the experimenter directed them to use the help manual.

Pilot testing had indicated that there was variance in the time it takes to complete the Access tasks during training, with participants in the low structure condition taking longer on average. Although previous studies have controlled for training time (Gully et al., 2002; Heimbeck et al., 2003), they have allowed participants in the high structure condition to repeat practice on the task, which, while eliminating the time confound, adds the confound of repeated practice. Research on age and training has also found that older learners take longer to work through self-paced training (e.g., Charness et al., 1992; Charness et al., 2001). The present study aimed to maximize the ecological validity of the design, and measured time taken in training, rather than controlling for it.
Materials

A training program on Microsoft Access software was developed for the purposes of this study. Access is a database package that is included in the Microsoft Office suite, which is sold globally. A program was developed to train a limited but manageable portion of Access, given the time constraints of the study. The training program was computer-based and individually delivered via an audio-visual Powerpoint presentation and several paper booklets (an example screen shot with corresponding script is shown in Appendix A). Pilot testing was conducted on 10 subjects, aged between 25 and 64 years old ($M = 38.7$, $SD = 14.9$), including administrative university staff and graduate students. This led to significant changes to the study design. For example, originally participants watched the training presentation then completed the practice tasks, but they tended to forget information presented early in the presentation. Following pilot feedback, practice tasks were interspersed in the training presentation. Also, the training content was modified to eliminate less relevant information and to expand areas which pilot feedback suggested needed further instruction.

All participants received a help manual with basic information on Access functions and some trouble-shooting advice. The manual avoided giving step-by-step instructions on how to apply the program’s functions. The help manual was designed following the guidelines for a “minimal manual” (Carroll, Smith-Kerker, Ford, & Mazur-Rimet, 1987; Lazonder & van der Meij, 1993; manual is shown in Appendix B). That is, information was task-oriented and focused on the basic goals that the program can achieve, but it is incomplete, leaving the trainee to explore when they can easily infer procedures. A minimal manual is jargon free where possible, and includes lots of
information on detecting and correcting errors. Finally, each section is self-contained, and does not require cross-referencing. The help manual was modified following pilot testing; specifically, trouble-shooting information was added for common mistakes encountered by the low structure training group.

All participants also received a training practice booklet, with detailed instructions to complete two orientation tasks in Access: opening a table and designing a basic query. These orientation tasks were included following feedback from pilot studies which indicated that participants in the low structure conditions struggled to get started in Access. The training practice booklet also presented five Access tasks that trainees worked on, and showed participants the correct results for each task and the number of records that should be returned by each query. Participants in the high structure conditions received additional information in their training practice booklet that was not available to participants in the low structure condition: detailed, step-by-step instructions to complete each task correctly, with screen shots for almost every step (see Appendices C and D).

Measures

Participants completed several scales throughout the experiment. Scales were presented via Survey Monkey or on a Windows computer using Medialab software.

Cognitive Ability

Cognitive ability was measured using the Wonderlic Personnel Test (Wonderlic & Associates, 1992). This 50-item test took 12 minutes to administer and assessed mathematical, verbal, logical reasoning, and spatial ability to create a general intelligence
score. Questions increased in difficulty, and participants completed as many questions as they were able to in the time allowed. The Wonderlic Personnel Test has been used extensively in psychological research and personnel selection as a measure of general cognitive ability (e.g., Bell & Kozlowski, 2002; Martocchio & Judge, 1997). The Wonderlic manual reports test-retest reliabilities between .82 and .94, parallel form reliabilities between .73 and .95, and internal consistency between .88 and .94 (Wonderlic & Associates, 1992).

*Learning Goal Orientation*

Trait goal orientation was measured using a 7-item scale developed by Zweig and Webster (2004). Participants responded using a 7-point scale ranging from 1 (strongly disagree) to 7 (strongly agree). Sample items include: “The opportunity to do challenging work is important to me” and “If I don't succeed on a difficult task, I plan to try harder the next time.” The reliability for this scale was α = .84.

*Metacognition*

Metacognitive activity was measured immediately following training using a 14-item scale adapted from Schmidt and Ford (2003). The scale was reworded to assess the degree to which participants engaged in metacognitive activity during the Access training. Participants responded using a 5-point scale ranging from 1 (almost never) to 5 (almost always). Example items include: “During this training program, I tried to change the way I learned in order to fit the demands of the situation or topic” and “During this training program, I thought carefully about how well my tactics for learning were working.” The reliability for this scale was α = .88.
Emotion Control

Emotion control was measured immediately following training using an 8-item scale ranging from 1(false) to 5(true), adapted from Keith and Frese (2005). Example items include: “When difficulties arose, I purposely continued to focus myself on the task,” and “When difficulties arose, I calmly considered how I could continue the task.” The reliability for this scale was $\alpha = .79$.

Self-efficacy

Self-efficacy was measured three times using 10-item scales adapted from Quinoñes (1995). Participants responded using a 5-point scale ranging from 1 (strongly disagree) to 5 (strongly agree). Self-efficacy for computer training was assessed before training commenced. An example item is: “I feel confident in my ability to perform well in this computer training.” Self-efficacy for Access knowledge and performance in an imminent test (the proximal predictor) was assessed after the training and practice sessions were complete, but prior to the first test session. An example item is: “I don’t feel that I am as capable of performing well in the Access test as other people” (reversescored). Self-efficacy for retention of Access knowledge for future use was assessed after the follow-up test session as a criterion measure. An example item is: “I think I can retain much of my Access knowledge.” The reliabilities for these scales were $\alpha = .80$ (self-efficacy for computer training), $\alpha = .81$ (self-efficacy for Access use), and $\alpha = .86$ (self-efficacy for Access retention).

Task Performance

Task performance was assessed on two occasions: immediately following practice (immediate task performance), and in the follow-up session one week later (delayed task performance).
Participants were given an Access database of a hypothetical company’s order information, including sales employee names, customer names, shipping address information (city, country, region), order dates, shipped dates, and freight costs.

As adaptive expertise is the goal of training, and the effects of error management training are typically observed with adaptive tasks, the test tasks were designed to assess adaptive performance. Rather than being given a description of a query design to complete (as in the practice tasks), participants were presented with a problem, in a business context, that required them to think about what query design would retrieve the appropriate information (see Appendix E). The participant’s task was to use their training to design a suitable query in Access, with appropriate criteria, and to save the query design. Participants were advised that the test tasks required them to use all of their training, and sometimes to go beyond it (e.g., using And and Or rules together). The tasks incorporated adaptive components that had not been directly trained. In addition, participants completed error-detection tasks, in which the aim of an Access query was described and participants examined the query design, and reported errors in the design.

Tasks were modified following feedback from pilot testing (see above). These modifications included reducing ambiguity in the description of the task problems, and adding hints for the most difficult adaptive components. The tasks were calibrated for difficulty, and have retained both simpler and more complex components, in order to increase variance in performance scores.

A scoring protocol was developed and pilot tested (see Appendix F). Tasks were broken down into meaningful subtasks, and points were assigned to each subtask. The scoring protocol included details on how to score all query design permutations, as well
as providing explicit scoring criteria for partial credit. Test scorers were trained on Access and were familiar with the task solutions. They also received training on use of the scoring protocol, using examples of possible query designs.

Knowledge Structures

Knowledge structures were assessed in the follow-up session one week after training. Participants were informed that the task measured the organization of their Access knowledge, and were shown an example of the concept rating task. Participants were advised that they would be making judgments of the relatedness of pairs of Access-related concepts (see Table 2).

Table 2. List of Access concepts for knowledge structure assessment, with node labels

<table>
<thead>
<tr>
<th>Node</th>
<th>Concept</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Designing a select query</td>
</tr>
<tr>
<td>2</td>
<td>Choosing fields to include in a query</td>
</tr>
<tr>
<td>3</td>
<td>Using the AND/OR rules</td>
</tr>
<tr>
<td>4</td>
<td>Using a Totals function (Count, Average, Sum, etc)</td>
</tr>
<tr>
<td>5</td>
<td>Applying criteria (e.g., date, location, name, cost) to return specific records</td>
</tr>
<tr>
<td>6</td>
<td>Performing an ascending or descending sort</td>
</tr>
<tr>
<td>7</td>
<td>Performing totals calculations (Count, Average, Sum, etc) using multiple fields of data</td>
</tr>
<tr>
<td>8</td>
<td>Switching views between Design and Datasheet view</td>
</tr>
<tr>
<td>9</td>
<td>Checking your query results are correct</td>
</tr>
<tr>
<td>10</td>
<td>Running a query</td>
</tr>
<tr>
<td>11</td>
<td>Checking the number of records returned by a query</td>
</tr>
</tbody>
</table>

They were shown all of the 11 Access concepts simultaneously, told to consider relatedness judgments relative to the other concepts in the list, and asked to select pairs of concepts to act as anchors on a scale of 1 (unrelated) to 7 (highly related). They were then shown the pairs of Access concepts sequentially, and rated their relatedness on the same 7-point scale. Participants rated every concept paired with every other concept, resulting
in \( n(n-1)/2 = 11(11-1)/2 = 55 \) relatedness judgments. The order of the pairs was randomized for each participant. Trainee concept ratings were submitted to the Pathfinder algorithm along with a composite set of expert ratings (Schvaneveldt, 1990), and a similarity index was calculated. The expert ratings were an average of the similarity ratings of three individuals who were very familiar with the Access training program, including the training designer. The intercorrelations between the similarity to expert ratings for the three experts and the composite measure are shown in Table 3.

*Table 3.* Intercorrelations of similarity to expert knowledge structures between the three Access experts and the composite expert

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Expert 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Expert 2</td>
<td>.632**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Expert 3</td>
<td>.321**</td>
<td>.401**</td>
<td></td>
</tr>
<tr>
<td>4. Composite</td>
<td>.865**</td>
<td>.622**</td>
<td>.235**</td>
</tr>
</tbody>
</table>

Using a composite expert measure reduced the effect of idiosyncrasies in individual raters. The composite expert’s knowledge structure is shown in Figure 3, and the node labels are presented in the figure note and in Table 2.

As pilot study feedback and consultation with other researchers suggested that the first few judgments were less reliable, six pairs of concepts were added to the start of the task, but were not used in the analysis of results. These ‘practice’ pairs were repeated in the actual rating task, resulting in a total of 61 concept pairs.

The 11 Access concepts were developed in consultation with several Access experts and using feedback from the pilot study. The concepts were first developed by the author, who received feedback from faculty and research assistants who were familiar
Figure 3. Knowledge structure of composite expert

Note. Node labels (also see Table 2): 1 = Designing a select query, 2 = Choosing fields to include in a query, 3 = Using the AND/OR rules, 4 = Using a Totals function (Count, Average, Sum, etc), 5 = Applying criteria (e.g., date, location, name, cost) to return specific records, 6 = Performing an ascending or descending sort, 7 = Performing totals calculations (Count, Average, Sum, etc) using multiple fields of data, 8 = Switching views between Design andDatasheet view, 9 = Checking your query results are correct, 10 = Running a query, 11 = Checking the number of records returned by a query.
with the content of the training program and had experience working with Access. The concepts were modified to reflect the procedural learning that typically occurs with software training, and detail was added to provide more information for the judgments (e.g., the concept “Criteria” was changed to “Applying criteria [e.g., date, location, name, cost] to return specific records”). The new concepts received approval from an Access expert with approximately 10 years experience working with the software.

*Attitude Towards Training*

Trainees typically prefer error-free training to error-prone training, and interpret error-free performance during training as evidence of effective instruction (Ghodsian et al., 1997). This was assessed with five items that asked participants to rate, on a scale of 1 (strongly disagree) to 7 (strongly agree), whether they liked the training and whether they believed it was effective (see Appendix G). The reliabilities for this scale were $\alpha = .79$ immediately after training and $\alpha = .87$ at the end of the follow-up session.

*Manipulation Checks*

As a manipulation check for instruction, the Learning From Errors subscale from the Error Orientation Questionnaire (Rybowiak, Garst, Frese, & Batinic, 1999) was adapted to reflect the training, rather than a work, context. The Learning From Errors subscale is a 4-item measure of the tendency to view errors positively and as helpful feedback for future performance. An example item is: “My mistakes help me to improve my performance,” and the reliability of this scale was $\alpha = .88$. It was anticipated that participants in the error encouragement instructions conditions would score higher on the Learning From Errors subscale than those in the no instructions condition.
As a manipulation check for structure, a 6-item scale was created to assess the degree to which participants made errors and experimented with their query design (see Appendix H). Participants responded on 5-point scale from 1 (never) to 5 (almost always). An example item is: “I tried several different options when trying to complete a practice task,” and the reliability of this scale was $\alpha = .90$.

*Computer Experience*

Computer experience was measured by a series of self-report items (see Appendix I). Participants were asked to rate their expertise on Microsoft Word, Microsoft Excel, Microsoft Powerpoint, database software, and computers in general using a 7-point scale ranging from 1 (never used) to 7 (true expert). In addition, participants estimated the number of hours they spend on a computer per day, and the number of years they have owned a computer. Computer experience was used as a covariate in all analyses.
RESULTS

The results section is organized in five parts. First, descriptive statistics and main effects will be presented, and procedures for creating the composite computer experience variable will be described. Second, the effects of error encouragement instructions on training outcomes will be presented. Third, the effects of structure on training outcomes will be described. Fourth, the results of the mediation analyses will be presented. Finally, data on comparative time taken in each of the training conditions and attitude towards training will be presented.

Preliminary Analyses

Table 4 displays descriptive statistics (means, standard deviations, and reliability estimates) for the predictor variables, overall and by condition. All scale reliability estimates reached adequate or high levels, as measured by Cronbach’s alpha. The distribution of cognitive ability scores is shown in Appendix J.

Table 5 presents descriptive statistics (means, standard deviations, reliability estimates) for the criterion variables (i.e., immediate and delayed task performance, knowledge structure assessments, and retention self-efficacy) overall and by condition. The distributions of all criterion variables are shown in Appendices K, L, M, and N.

Participants were randomly assigned to condition; therefore no differences on distal predictors or the computer experience covariate were anticipated. As shown in Table 4, random assignment to condition did not result in any differences between conditions with respect to age, cognitive ability, learning goal orientation, or computer experience.
Table 4. Number of items, Cronbach’s alpha, means, and standard deviations for predictor variables, overall and by condition

<table>
<thead>
<tr>
<th>Predictor Variables</th>
<th># Items</th>
<th>Overall</th>
<th>HE</th>
<th>HN</th>
<th>LE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>α</td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>Age</td>
<td>1</td>
<td>--</td>
<td>39.7</td>
<td>13.4</td>
<td>40.6</td>
</tr>
<tr>
<td>Cognitive Ability</td>
<td>50</td>
<td>--</td>
<td>25.2</td>
<td>7.2</td>
<td>25.0</td>
</tr>
<tr>
<td>Learning Goal Orientation</td>
<td>7</td>
<td>.84</td>
<td>5.8</td>
<td>.8</td>
<td>5.8</td>
</tr>
<tr>
<td>Computer Experience</td>
<td>3</td>
<td>.78</td>
<td>3.7</td>
<td>1.5</td>
<td>3.6</td>
</tr>
<tr>
<td>Self-Efficacy (Training)</td>
<td>10</td>
<td>.80</td>
<td>3.9</td>
<td>.8</td>
<td>3.9</td>
</tr>
<tr>
<td>Emotion Control</td>
<td>8</td>
<td>.79</td>
<td>4.6</td>
<td>.6</td>
<td>4.7</td>
</tr>
<tr>
<td>Metacognitive Activity</td>
<td>14</td>
<td>.88</td>
<td>3.5</td>
<td>.8</td>
<td>3.6</td>
</tr>
<tr>
<td>Self-Efficacy (Access Use)</td>
<td>10</td>
<td>.81</td>
<td>4.1</td>
<td>.6</td>
<td>3.4</td>
</tr>
</tbody>
</table>

*Note. HE = high structure + error encouragement instructions, HN = high structure + no instructions, LE = low structure + error encouragement instructions. Overall N = 161, HE N = 57, HN N = 52, LE N = 52*
Table 5. Number of items, Cronbach’s alpha, means, and standard deviations for criterion variables, overall and by condition

<table>
<thead>
<tr>
<th></th>
<th>Overall</th>
<th>HE</th>
<th>HN</th>
<th>LE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td># Items</td>
<td>α</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Criterion Variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task Performance (Immed)</td>
<td>--</td>
<td>--</td>
<td>111.5</td>
<td>37.9</td>
</tr>
<tr>
<td>Task Performance (Delayed)</td>
<td>--</td>
<td>--</td>
<td>85.6</td>
<td>29.6</td>
</tr>
<tr>
<td>Knowledge Structure</td>
<td>55</td>
<td>--</td>
<td>.27</td>
<td>.08</td>
</tr>
<tr>
<td>Self-efficacy (Retention)</td>
<td>10</td>
<td>.86</td>
<td>3.5</td>
<td>.8</td>
</tr>
</tbody>
</table>

Note. HE = high structure + error encouragement instructions, HN = high structure + no instructions, LE = low structure + error encouragement instructions. Immed = Immediate. Overall N = 161, HE N = 57, HN N = 52, LE N = 52.
Table 6. Intercorrelations of study variables

<table>
<thead>
<tr>
<th>Variables</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Age</td>
<td>.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>2. Comp Experience</td>
<td>-.365**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Cognitive Ability</td>
<td>-.007</td>
<td>.154</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Learning GO</td>
<td>-.074</td>
<td>.075</td>
<td>.013</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>5. SE Training</td>
<td>-.054</td>
<td>.216**</td>
<td>.058</td>
<td>.269**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Emotion Control</td>
<td>-.006</td>
<td>.146</td>
<td>-.101</td>
<td>.220**</td>
<td>.169*</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. SE Access Use</td>
<td>-.079</td>
<td>.194*</td>
<td>.111</td>
<td>.259**</td>
<td>.500**</td>
<td>.381**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Metacognition</td>
<td>.068</td>
<td>-.137</td>
<td>-.154</td>
<td>.278**</td>
<td>.143</td>
<td>.093</td>
<td>.055</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. SE Retention</td>
<td>-.111</td>
<td>.327**</td>
<td>.154</td>
<td>.241**</td>
<td>.364**</td>
<td>.340**</td>
<td>.421**</td>
<td>.148</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Imm Task Perf</td>
<td>-.271**</td>
<td>.429**</td>
<td>.555**</td>
<td>.028</td>
<td>.118</td>
<td>.103</td>
<td>.249**</td>
<td>-.099</td>
<td>.366**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Del Task Perf</td>
<td>-.232**</td>
<td>.344**</td>
<td>.517**</td>
<td>-.001</td>
<td>.167*</td>
<td>.093</td>
<td>.226**</td>
<td>-.056</td>
<td>.418**</td>
<td>.788**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Know Structure</td>
<td>-.214</td>
<td>.055</td>
<td>.237**</td>
<td>-.145</td>
<td>-.042</td>
<td>-.017</td>
<td>.010</td>
<td>.024</td>
<td>.111</td>
<td>.310**</td>
<td>.200*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Att Training T1</td>
<td>.222**</td>
<td>-.186*</td>
<td>-.168*</td>
<td>.070</td>
<td>-.038</td>
<td>.160*</td>
<td>.126</td>
<td>.350**</td>
<td>.126</td>
<td>-.177*</td>
<td>-.103</td>
<td>-.083</td>
<td></td>
</tr>
<tr>
<td>14. Att Training T2</td>
<td>.024</td>
<td>.005</td>
<td>.029</td>
<td>.055</td>
<td>-.035</td>
<td>.164*</td>
<td>.074</td>
<td>.097</td>
<td>.454**</td>
<td>.027</td>
<td>.091</td>
<td>.030</td>
<td>.507**</td>
</tr>
</tbody>
</table>

Note. Comp Experience = computer experience, Learning GO = learning goal orientation, SE Training = self-efficacy for computer training, SE Access Use = self-efficacy for Access use, Imm Task Perf = immediate task performance, Del Task Perf = delayed task performance, Know Structure = similarity to expert’s knowledge structure, Att Training T1 = attitude towards training immediate measure, Att Training T2 = attitude towards training delayed measure.
* denotes p < .05, ** denotes p < .01
Table 6 presents the intercorrelations of all study variables. Of note in the table is the correlation between age and computer experience, which is significantly negative, reinforcing the need to develop computer training suited to the needs of older learners. Also, the correlation between age and cognitive ability is not significant in this study. This is perhaps a function of the test used to assess cognitive ability. The Wonderlic test assesses both fluid and crystallized components of ability (i.e., has some items that tap existing knowledge, and others that require novel problem solving, memory, and speed). Previous research has found that age is negatively related to working memory and the processing of novel information that are characteristic of fluid ability, whereas age is positively related to acquired knowledge that is characteristic of crystallized ability (Beier & Ackerman, 2001, 2003). Because the Wonderlic potentially taps both of these abilities in one aggregate measure, it is likely that the decrements in fluid ability associated with age are offset by the stability or increases in crystallized ability in scores on this measure.

Computer Experience Covariate

Participants were asked to report their computer experience on a seven item scale (see Appendix I). The internal consistency reliability estimate of the scale including all seven items was only $\alpha = .50$. In terms of individual items, self-rated expertise with Microsoft Word, Microsoft Powerpoint, and Microsoft Excel were strongly related to scores on the task performance and self-efficacy outcomes. Therefore a composite computer experience scale was created, comprising these three items. Principal components analysis confirmed that these items loaded onto a single factor that
accounted for 69.8% of the variance. Despite the low number of items in the composite scale, the internal consistency reliability estimate was high, $\alpha = .78$. This three item composite is used as the measure of computer experience in subsequent analyses.

The composite computer experience scale was highly related to all training outcomes, with the exception of the knowledge structure measure. Therefore, computer experience was used as a covariate in all analyses. Before proceeding with analyses, it was established that there was no interaction between the computer experience covariate and any of the training outcomes to ensure that the relationship between the covariate and the dependent measures was equal across all conditions.

**Main Effects**

*Training Condition*

The main effect of training condition on three training outcomes was first assessed in MANCOVA. Controlling for computer experience, training condition was marginally significant for the overall model (Wilk's Lambda: $F(8, 308) = 1.94, p = .054$, partial $\eta^2 = .05$). Analysis of individual training outcomes revealed that there was an overall effect of condition on immediate task performance, $F(2, 157) = 5.09, p = .007$, partial $\eta^2 = .06$; delayed task performance, $F(2, 157) = 3.20, p = .043$, partial $\eta^2 = .04$; and self-efficacy for retention of Access knowledge, $F(2, 157) = 3.30, p = .039$, partial $\eta^2 = .04$. However, there was no overall effect of training condition on similarity to an expert's knowledge structure, $F(2, 157) = 1.80, p = .169$. Inspection of Table 5 revealed that the low structure + error encouragement instructions training condition yielded the best performance and highest self-efficacy, followed by the high structure + error
encouragement instructions condition. The high structure + no instructions training condition resulted in the poorest performance, overall.

Pairwise comparisons found that, for immediate task performance, the low structure + error encouragement instructions condition resulted in superior performance compared to the high structure + error encouragement instructions condition, $F(1, 106) = 3.94, p = .050$, partial $\eta^2 = .04$; and compared to the high structure + no instructions condition, $F(1, 101) = 9.95, p = .002$, partial $\eta^2 = .09$. However, no difference was detected on immediate task performance between the high structure + error encouragement instructions condition and the high structure + no instructions condition, $F(1, 106) = 1.53, p = .219$. For delayed task performance, the low structure + error encouragement instructions condition resulted in superior performance compared to the high structure + no instructions condition, $F(1, 101) = 6.62, p = .012$, partial $\eta^2 = .06$. No difference was detected on delayed task performance between the low structure + error encouragement instructions condition and the high structure + error encouragement instructions condition, $F(1, 106) = 1.33, p = .251$; or between the high structure + error encouragement instructions condition and the high structure + no instructions condition, $F(1, 106) = 1.90, p = .172$. For retention self-efficacy, the low structure + error encouragement instructions condition resulted in higher self-efficacy compared to the high structure + no instructions condition, $F(1, 101) = 6.81, p = .010$, partial $\eta^2 = .06$. No difference was detected on retention self-efficacy between the low structure + error encouragement instructions condition and the high structure + error encouragement instructions condition, $F(1, 106) = 3.31, p = .072$; or between the high structure + error
encouragement instructions condition and the high structure + no instructions condition, 
\( F(1, 106) = .27, p = .606. \)

*Cognitive Ability*

The correlations between predictor and criterion variables by condition are shown in Tables 7, 8, and 9. As can be seen in the tables, cognitive ability was highly related to immediate and delayed task performance across all conditions, and was significantly related to similarity to an expert’s knowledge structure for two of the three conditions (the relation between ability and knowledge structures failed to reach significance in the high structure + no instruction condition). However, cognitive ability was not significantly related to self-efficacy for retention in any condition. These results confirmed that cognitive ability was an important predictor of performance for cognitive training outcomes, but not for the more affectively-oriented outcome of self-efficacy.
Table 7. Correlations between predictors and training outcomes in high structure + error encouragement instructions condition

<table>
<thead>
<tr>
<th>Variables</th>
<th>Imm Task Perf</th>
<th>Del Task Perf</th>
<th>Know Structure</th>
<th>SE Retention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>-.169</td>
<td>-.059</td>
<td>-.237</td>
<td>.068</td>
</tr>
<tr>
<td>Cognitive Ability</td>
<td>.580**</td>
<td>.536**</td>
<td>.315*</td>
<td>.247</td>
</tr>
<tr>
<td>Learning Goal Orientation</td>
<td>.067</td>
<td>-.002</td>
<td>-.209</td>
<td>.231</td>
</tr>
<tr>
<td>Self-efficacy (Training)</td>
<td>.189</td>
<td>.110</td>
<td>.014</td>
<td>.315*</td>
</tr>
<tr>
<td>Emotion Control</td>
<td>.246</td>
<td>.305*</td>
<td>.065</td>
<td>.350**</td>
</tr>
<tr>
<td>Metacognition</td>
<td>-.135</td>
<td>-.115</td>
<td>-.141</td>
<td>.079</td>
</tr>
<tr>
<td>Self-efficacy (Access use)</td>
<td>.260</td>
<td>.239</td>
<td>-.015</td>
<td>.368**</td>
</tr>
</tbody>
</table>

Note. N = 57. Imm Task Perf = immediate task performance, Del Task Perf = delayed task performance, Know Structure = similarity to expert’s knowledge structure, SE Retention = self-efficacy for retention of Access knowledge. * denotes p < .05, ** denotes p < .01
Table 8. Correlations between predictors and training outcomes in high structure + no instructions condition

<table>
<thead>
<tr>
<th>Variables</th>
<th>Imm Task Perf</th>
<th>Del Task Perf</th>
<th>Know Structure</th>
<th>SE Retention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>-.277**</td>
<td>-.248</td>
<td>-.089</td>
<td>-.085</td>
</tr>
<tr>
<td>Cognitive Ability</td>
<td>.606**</td>
<td>.559**</td>
<td>.127</td>
<td>.085</td>
</tr>
<tr>
<td>Learning Goal Orientation</td>
<td>-.046</td>
<td>.018</td>
<td>.087</td>
<td>.244</td>
</tr>
<tr>
<td>Self-efficacy (Training)</td>
<td>.101</td>
<td>.137</td>
<td>-.023</td>
<td>.542**</td>
</tr>
<tr>
<td>Emotion Control</td>
<td>-.055</td>
<td>-.171</td>
<td>-.265</td>
<td>.178</td>
</tr>
<tr>
<td>Metacognition</td>
<td>-.146</td>
<td>-.167</td>
<td>.208</td>
<td>.040</td>
</tr>
<tr>
<td>Self-efficacy (Access Use)</td>
<td>.184</td>
<td>.079</td>
<td>-.053</td>
<td>.401**</td>
</tr>
</tbody>
</table>

Note. N = 52. Imm Task Perf = immediate task performance, Del Task Perf = delayed task performance, Know Structure = similarity to expert’s knowledge structure, SE Retention = self-efficacy for retention of Access knowledge. * denotes p < .05, ** denotes p < .01
Table 9. Correlations between predictors and training outcomes in low structure + error encouragement instructions condition

<table>
<thead>
<tr>
<th>Variables</th>
<th>Imm Task Perf</th>
<th>Del Task Perf</th>
<th>Know Structure</th>
<th>SE Retention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>-.320*</td>
<td>-.375**</td>
<td>-.264</td>
<td>-.278*</td>
</tr>
<tr>
<td>Cognitive Ability</td>
<td>.563**</td>
<td>.501**</td>
<td>.280*</td>
<td>.137</td>
</tr>
<tr>
<td>Learning Goal Orientation</td>
<td>.114</td>
<td>.040</td>
<td>-.182</td>
<td>.337*</td>
</tr>
<tr>
<td>Self-efficacy (Training)</td>
<td>-.058</td>
<td>-.294*</td>
<td>.001</td>
<td>-.250</td>
</tr>
<tr>
<td>Emotion Control</td>
<td>.181</td>
<td>.214</td>
<td>.138</td>
<td>.566**</td>
</tr>
<tr>
<td>Metacognition</td>
<td>-.117</td>
<td>.037</td>
<td>.025</td>
<td>.295*</td>
</tr>
<tr>
<td>Self-efficacy (Access Use)</td>
<td>.330*</td>
<td>.408*</td>
<td>.096</td>
<td>.550**</td>
</tr>
</tbody>
</table>

Note. $N = 52$. Imm Task Perf = immediate task performance, Del Task Perf = delayed task performance, Know Structure = similarity to expert’s knowledge structure, SE Retention = self-efficacy for retention of Access knowledge. * denotes $p < .05$, ** denotes $p < .01$
Components of Training

As the three training conditions represented different combinations of structure and instruction, it was more informative to compare two of the conditions at one time. Comparison of performance on training outcomes in the high structure + error encouragement instructions condition to performance in the high structure + no instructions condition permitted the examination of the effect of instruction, while controlling for structure. Whereas comparison of performance in the high structure + error encouragement instructions condition to performance in the low structure + error encouragement instructions condition permitted the examination of the effect of structure, while controlling for instructions. The comparisons are examined in the analyses that follow.

Effect of Instruction

The effect of instruction on training outcomes was investigated by comparing performance in the high structure + error encouragement instructions condition to performance in the high structure + no instructions condition. It should be noted that the independent effect of instruction was tested only under high structure conditions. Results will be presented from the manipulation check, followed by main effects, and interaction effects.

Manipulation Check

The error encouragement instructions reinforced the notion that errors were beneficial for learning and should be regarded as positive opportunities, and the learning
from errors scale assessed whether participants felt positively about making mistakes. No
difference was detected on the learning from errors scale between the high structure +
error encouragement instructions condition \((M = 4.12, SD = .66)\) and the high structure +
no instructions condition \((M = 4.06, SD = .76)\), \(F(1, 106) = .24, p = .625\). Even though
the results of the manipulation check did not differ across conditions, interesting
differences were found between the conditions (conditions that were identical except for
the error encouragement instructions). This suggests that participants may not have been
consciously aware of the instructions and/or that the learning from errors scale may be an
ineffective manipulation check to distinguish the effect of the error encouragement
instructions within high structure conditions.

**Main Effects**

The main effect of instruction was tested in a series of ANCOVAs. This
procedure allowed for an examination of differences between groups, while controlling
for some variables, and examining interactions and variance accounted for by other
variables. Controlling for computer experience, no effect of instruction was detected on
any of the training outcomes: immediate task performance, \(F(1, 106) = 1.53, p = .219\);
delayed task performance, \(F(1, 106) = 1.90, p = .172\), self-efficacy for retention of
Access knowledge, \(F(1, 106) = .27, p = .606\), and similarity to an expert’s knowledge
structure, \(F(1, 106) = .01, p = .913\).

No statistically significant main effect of age was found on any of the training
outcomes: immediate task performance, \(F(1, 106) = 2.92, p = .091\); delayed task
performance, \(F(1, 106) = 1.15, p = .287\); self-efficacy for retention of Access knowledge,
\(F(1, 106) = .25, p = .617\); and similarity to an expert’s knowledge structure, \(F(1, 106) = 3.32, p = .071\).

Learning goal orientation is typically associated with better performance in training, and a main effect was detected for self-efficacy for retention of Access knowledge, \(F(1, 106) = 5.85, p = .017\), partial \(\eta^2 = .05\). This result indicated that trainees high on learning goal orientation reported greater self-efficacy for retention of Access knowledge at the end of the study. But no main effect was found for the remaining three outcomes: immediate task performance, \(F(1, 106) < .01, p = .986\); delayed task performance, \(F(1, 106) = .01, p = .912\); and similarity to an expert’s knowledge structure, \(F(1, 106) = 1.09, p = .300\).

**Two-way Interaction Effects of Predictors and Instruction**

Of greater interest were the interactive effects between the variables, which may reveal aptitude-treatment interactions on training outcomes. To examine these effects, two-way interactive effects of instruction and age, and of instruction and learning goal orientation, were tested using ANCOVA. Age was expected to interact with instructions, such that older trainees would benefit more from error encouragement instructions than younger trainees. Controlling for computer experience, no interactive effects of age and instruction were found on any of the training outcomes: immediate task performance, \(F(1, 104) = .49, p = .484\); delayed task performance, \(F(1, 104) = 1.24, p = .268\); self-efficacy for retention of Access knowledge, \(F(1, 104) = .90, p = .346\); and similarity to an expert’s knowledge structure, \(F(1, 104) = 1.13, p = .290\).
An interaction of learning goal orientation and training instruction was predicted, such that participants high on learning goal orientation would perform better on training outcomes with error encouragement instructions, as the instructions correspond with their dispositional tendency to perceive errors as learning opportunities. However, after controlling for computer experience, the univariate analyses failed to detect an interactive effect of learning goal orientation and instruction on any of the training outcomes: immediate task performance, $F(1, 104) = .20, p = .658$; delayed task performance, $F(1, 104) = .05, p = .818$; self-efficacy for retention of Access knowledge, $F(1, 104) = .07, p = .792$; and similarity to an expert’s knowledge structure, $F(1, 104) = 2.11, p = .149$.

**Three-way Interaction Effects of Predictors and Instruction**

The absence of any two-way interactions, particularly between age and instruction on task performance, was somewhat puzzling. An examination of the correlations between age and task performance in the high structure + error encouragement instructions condition and in the high structure + no instructions condition was suggestive of an interactive effect (see Tables 7 and 8). The magnitude of the negative relationship between age and immediate task performance was weaker in the high structure + error encouragement instructions condition ($r = -.169, p > .05$) than in the high structure + no instructions condition ($r = -.277, p < .01$). A similar pattern was evident for delayed task performance: although neither correlation reached significance, there was a weaker negative correlation between age and performance in the high structure + error encouragement instructions condition ($r = -.059, p > .05$) than in the high structure + no instructions condition ($r = -.248, p > .05$).
To investigate further, a three-way interaction between age, cognitive ability, and instruction was tested. Cognitive ability is known to be a strong predictor of training performance, as it was in this study. It was conceivable that the hypothesized beneficial effect of error encouragement instructions for older trainees may, in fact, depend on their level of cognitive ability. This hypothesized age x cognitive ability x instruction interaction in task performance was investigated using ANCOVA, controlling for computer experience. The results revealed a significant three-way interaction for immediate task performance: $F(1, 100) = 4.32, p = .040$, partial $\eta^2 = .04$. Furthermore, the interaction had a greater effect on delayed task performance: $F(1, 100) = 5.99, p = .016$, partial $\eta^2 = .06$. Inspection of the age x cognitive ability x instruction interaction revealed an interesting pattern of effects across age and ability groups, suggestive of a quadratic effect of age. Indeed, a quadratic effect of age that approached statistical significance was observed in the interaction for immediate task performance: $F(1, 96) = 3.06, p = .083$, partial $\eta^2 = .03$. This age (quadratic) x cognitive ability x instruction interaction was clearly significant after a retention interval: $F(1, 96) = 5.15, p = .025$, partial $\eta^2 = .05$, for delayed task performance. The results showed that the error encouragement instructions differentially helped low and high cognitive ability trainees, depending on their age, and that the differential effect due to age was non-linear.

To aid interpretation of the three-way interaction, the age and cognitive ability variables were divided into three groups in order to plot the interaction (although all statistics were computed on continuous data). The groups comprised the 33\textsuperscript{rd} percentile and below, between the 33\textsuperscript{rd} and 66\textsuperscript{th} percentiles, and the 66\textsuperscript{th} percentile and above. For age, these percentiles corresponded approximately to 20 to 31 years old, 31 to 47 years
old, and 47 to 66 years old. For cognitive ability, these percentiles corresponded approximately to a score of between 7 and 22, between 22 and 28, and between 28 and 41, on the Wonderlic test (which had a maximum score of 50). For ease of discussion, these groups will be referred to as young, middle-aged, and old (for age), and low, medium, and high ability (for cognitive ability). For ease of interpretation, the age variable is plotted in the interaction, rather than the quadratic function of age.

The interaction plots displaying the age x cognitive ability x instruction interaction for immediate task performance in the different age groups (see Figure 4) show that there was little effect of error encouragement instructions for young trainees with high or medium levels of cognitive ability (at high levels of cognitive ability, the error encouragement instructions may have even been slightly detrimental to performance). But if a young trainee had low cognitive ability, then the error encouragement instructions enhanced performance. For middle-aged trainees, the error encouragement instructions boosted performance regardless of level of cognitive ability. This beneficial effect appeared to be strongest at medium levels of ability. For older trainees, the error encouragement instructions augmented performance when the trainees had high or medium levels of cognitive ability. However, the instructions appeared to be detrimental to performance for older trainees with low cognitive ability. It was also noteworthy that, controlling for computer experience, older high ability participants could match the performance of younger high ability participants, if the older participants had the error encouragement instructions.
Figure 4. Age x cognitive ability x effect of instruction interaction for immediate task performance

Young Participants

Middle-aged Participants

Old Participants
Figure 5. Age x cognitive ability x effect of instruction interaction for delayed task performance

Young Participants

Middle-aged Participants

Old Participants
An examination of the interaction for delayed task performance was particularly pertinent to the goals of this study, which aimed to study training designs that boosted transfer performance. Figure 5 shows the same age x cognitive ability x instruction interaction for delayed task performance in the different age groups. After a week-long retention interval, a similar pattern of performance differences, dependent on age and ability, can be seen as for immediate task performance. There was a slight negative effect of error encouragement instructions for young trainees with high levels of ability, and a slight positive effect of error encouragement instructions for young trainees with medium levels of ability. But the error encouragement instructions resulted in a considerable performance boost for young trainees with low cognitive ability. There was no effect of instructions for middle-aged trainees with high levels of cognitive ability, suggesting that the slight performance increment observed with immediate task performance was not sustained over time. However, for middle-aged trainees with medium or low levels of cognitive ability, there was an improvement in performance with error encouragement instructions. A benefit of instruction was evident on immediate task performance for medium ability trainees in particular, but the effect of these instructions for low ability trainees was less prominent. Yet, after a retention interval, error encouragement instructions resulted in enhanced performance, particularly for low ability trainees. Comparison of the interaction plots for immediate and delayed task performance for older trainees shows a similar pattern of results across time. Error encouragement instructions were beneficial for performance for trainees with high or medium levels of cognitive ability, and the augmentation effect on performance appeared to be stronger after a delay.
Although slight, the error encouragement instructions were again detrimental to performance for older trainees with low levels of cognitive ability.

As was reported for immediate performance, when computer experience was controlled, older high ability participants could match the delayed task performance scores of younger high ability participants, if the older participants had the error encouragement instructions.

The quadratic effect of age in this interaction on delayed task performance is evident from the non-linear variation in the relative effect of error encouragement instructions on trainees with different levels of ability, at different ages. More specifically, for younger trainees, the error encouragement instructions helped low ability trainees slightly more than medium-high ability trainees. For middle-aged trainees, the error encouragement instructions helped low-medium ability trainees considerably more than high ability trainees. For older trainees, the error encouragement instructions helped low ability trainees slightly less than medium-high ability trainees. In fact, for older trainees, the trend is reversed, such that the error encouragement instructions slightly hinder low ability trainees more than medium-high ability trainees.

Figure 6 shows this interaction for immediate task performance using difference scores. The beneficial effects of error encouragement instructions are represented by positive scores, and the detrimental effects of error encouragement instructions are represented by negative scores. These difference scores were computed by taking the difference in task performance score due to the effect of instruction (i.e., score in high structure + error encouragement instructions condition minus the score in high structure + no instructions condition) for each combination of the cognitive ability and age groups.
For example, examination of Figure 4 for young participants shows that young, high ability trainees have higher immediate task performance scores without error encouragement instructions. This is represented as a negative difference score in Figure 6 (approximately 128-143 = -15). As shown in Figure 4 for old participants, old high ability trainees have higher immediate task performance scores with the error encouragement instructions. This is represented by a positive difference score in Figure 6 (approximately 143-120 = +23). Figure 7 shows these same data for delayed task performance.

In summary, an age x cognitive ability x instruction interaction accounted for differences in immediate and delayed task performance. The linear effect of age in this interaction was significant for immediate performance and after a retention interval, and the quadratic effect of age in this interaction was significant after the retention interval.
Figure 6. Age x cognitive ability x effect of instruction interaction for immediate task performance (difference scores)

Figure 7. Age x cognitive ability x effect of instruction interaction for delayed task performance (difference scores)
Effect of Structure

The effect of structure on training outcomes was investigated by comparing performance in the low structure + error encouragement instructions condition to performance in the high structure + error encouragement instructions condition. It should be noted that the effect of structure is being tested only under error encouragement conditions.

Results will be presented from the manipulation check, followed by main effects, and interaction effects.

Manipulation Check

In the high structure condition, participants received detailed instructions, enabling them to complete the practice tasks correctly on their first try; whereas in the low structure condition, participants were not told how to do the practice tasks and were expected to make mistakes and try out different query designs. The training structure scale assessed whether participants actually made errors and experimented with the computer program.

An ANCOVA was performed to check for differences on the training structure scale. As expected, participants in the low structure + error encouragement instructions condition reported greater error commission and experimentation with their query designs ($M = 3.28, SD = .98$) than participants in the high structure + error encouragement instructions condition ($M = 1.94, SD = .73$), $F(1, 106) = 93.7, p < .001$, partial $\eta^2 = .47$).
Main Effects

The main effect of structure was tested using ANCOVAs. Controlling for computer experience, there was an effect of structure on immediate task performance, such that low structure training resulted in better immediate task performance than high structure training, $F(1, 106) = 3.94, p = .050$, partial $\eta^2 = .04$. But no effect of structure was detected on the remaining three training outcomes: delayed task performance, $F(1, 106) = 1.33, p = .251$; self-efficacy for retention of Access knowledge, $F(1, 106) = 3.31, p = .072$; and similarity to an expert’s knowledge structure, $F(1, 106) = 2.22, p = .140$.

ANCOVAs testing the main effect of age found an effect of age on similarity to an expert’s knowledge structure, suggesting that the knowledge structures of younger learners were more similar to an expert’s than were the knowledge structures of older learners, $F(1, 106) = 5.22, p = .024$, partial $\eta^2 = .05$. But no main effect of age was detected on the other training outcomes: immediate task performance, $F(1, 106) = .50, p = .480$; delayed task performance, $F(1, 106) = .39, p = .534$; and self-efficacy for retention of Access knowledge, $F(1, 106) = .88, p = .351$.

There was a main effect of learning goal orientation, controlling for computer experience, on self-efficacy for retention of Access knowledge, $F(1, 106) = 6.01, p = .016$, partial $\eta^2 = .05$, and for similarity to an expert’s knowledge structure, $F(1, 106) = 5.78, p = .018$, partial $\eta^2 = .05$. Trainees high in learning goal orientation tended to report greater self-efficacy for retention, but had poorer knowledge structures. No main effect was found for the task performance outcomes: immediate task performance, $F(1, 106) = .06, p = .809$; or for delayed task performance, $F(1, 106) = .41, p = .709$. 
Two-way Interaction Effects of Predictors and Structure

A series of aptitude-treatment interactions, controlling for computer experience, was tested using ANCOVAs. The two-way interactive effects of structure and the distal predictors of age, cognitive ability, and learning goal orientation on training outcomes were investigated.

It was predicted that age would interact with structure, such that older trainees would perform better in high structure training compared to low structure training, whereas younger trainees would perform better in low structure training compared to high structure training. Controlling for computer experience, no interactive effect of age and structure was found for any of the training outcomes: immediate task performance, $F(1, 104) = .02, p = .878$; delayed task performance, $F(1, 104) = .58, p = .448$; self-efficacy for retention of Access knowledge, $F(1, 104) = .79, p = .375$; and similarity to an expert’s knowledge structure, $F(1, 104) < .01, p = .986$.

It was hypothesized that cognitive ability would interact with structure, such that high ability trainees would perform better in low structure training than in high structure training, whereas low ability trainees would perform better in high structure training than in low structure training. However, after controlling for computer experience, no interactive effects of cognitive ability and structure were detected on any of the training outcomes: immediate task performance, $F(1, 104) = .01, p = .913$; delayed task performance, $F(1, 104) = .31, p = .576$; self-efficacy for retention of Access knowledge, $F(1, 104) = .72, p = .398$; and similarity to an expert’s knowledge structure, $F(1, 104) < .01, p = .992$. 

It was expected that learning goal orientation would interact with structure, such that trainees with a high learning goal orientation would perform better on task performance and report higher retention self-efficacy following low structure training than following high structure training. Univariate analyses did not find an interactive effect of learning goal orientation and structure on any of the training outcomes: immediate task performance, $F(1, 104) = .02, p = .891$; delayed task performance, $F(1, 104) = .02, p = .900$; self-efficacy for retention of Access knowledge, $F(1, 104) = .05, p = .832$; and similarity to an expert’s knowledge structure, $F(1, 104) = .02, p = .889$.

**Three-way Interaction Effects of Predictors and Instruction**

Examination of the correlations between age and task performance in the high structure + error encouragement instructions condition and in the low structure + error encouragement instructions condition was suggestive of an interactive effect (see Tables 7 and 9). The magnitude of the negative relationship between age and immediate task performance was weaker in the high structure + error encouragement instructions condition ($r = -.169$, $p > .05$) than in the low structure + error encouragement instructions condition ($r = -.320$, $p < .05$). A similar pattern was evident for delayed task performance: the negative relationship between age and delayed task performance was weaker in the high structure + error encouragement instructions condition ($r = -.059$, $p > .05$) than in the low structure + error encouragement instructions condition ($r = -.375$, $p < .01$). An age x ability x effect of structure interaction was tested, but was not significant for immediate $F(1, 100) = .30, p = .586$, or delayed task performance, $F(1, 100) = 1.08, p = .301$. 
In summary, there was a main effect of structure on immediate task performance, a main effect of age on knowledge structures, and a main effect of learning goal orientation on self-efficacy and knowledge structures. The data did not support the predictions of a two-way, or exploratory three-way, interaction.

**Mediation Analyses**

According to the resource allocation perspective, distal predictors influence training outcomes via more proximal self-regulatory processes, such as emotion control, metacognitive activity, and self-efficacy. This study sought to test these hypothesized relationships between cognitive ability and learning goal orientation (distal predictors) and training outcomes, as mediated by self-regulatory processes.

Mediation is typically established using the four criteria outlined by Baron and Kenny (1986). To demonstrate mediation: (1) the distal predictor must be related to the outcome measure of interest; (2) the distal predictor must be related to the mediator; (3) the mediator must be related to the outcome measure after the effect of the distal predictor has been accounted for; and (4) the effect of the distal predictor on the outcome measure should be zero, after controlling for the mediator. If criteria 1 through 4 are met, then there is evidence for full mediation. If criteria 1 through 3 are met, then there is evidence for partial mediation.

The correlations between distal predictors, self-regulatory processes, and training outcomes were examined (see Table 6 for the overall correlations, and Tables 7, 8, and 9 for correlations by condition). Cognitive ability did not correlate to a statistically significant degree with any of the self-regulatory processes of emotion control,
metacognitive activity, or self-efficacy. Learning goal orientation correlated with several self-regulatory processes, but there were a limited number of statistically significant relationships between self-regulatory processes and training outcomes. However, inspection of these correlation tables did suggest that further investigation into the effect of emotion control on the relationship between learning goal orientation and self-efficacy for Access retention was warranted.

The mediating role of emotion control in the relationship between learning goal orientation and self-efficacy for Access retention was tested separately for the two high structure training conditions and for the two error encouragement instructions conditions, using Baron and Kenny’s (1986) criteria. No mediation effect was detected for the two high structure training conditions. However, emotion control was found to fully mediate the relationship between learning goal orientation and self-efficacy in the two error encouragement instructions conditions. The results of the regression analyses testing for mediation for the two error encouragement instructions conditions are shown in Table 10. Learning goal orientation was found to predict self-efficacy for Access retention (criterion 1); learning goal orientation was found to predict emotion control (criterion 2); and emotion control was found to predict self-efficacy for Access retention, after controlling for the effect of learning goal orientation (criterion 3). Finally, learning goal orientation no longer predicted self-efficacy after controlling for emotion control, suggesting full mediation (criterion 4).
Table 10. Summary of hierarchical regression analysis for emotion control as a mediator of learning goal orientation effects on immediate task performance, for the error encouragement instructions conditions.

<table>
<thead>
<tr>
<th>Step and Variable</th>
<th>B</th>
<th>SE B</th>
<th>β</th>
<th>R²</th>
<th>ΔR²</th>
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</thead>
<tbody>
<tr>
<td>Direct effect of learning goal orientation on self-efficacy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DV = Self-efficacy</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Step 1: Computer experience (control)</td>
<td>.07</td>
<td>.02</td>
<td>.38**</td>
<td>.16</td>
<td>.16**</td>
</tr>
<tr>
<td>Step 2: Learning goal orientation</td>
<td>.19</td>
<td>.08</td>
<td>.21*</td>
<td>.21</td>
<td>.05*</td>
</tr>
<tr>
<td>Direct effect of learning goal orientation on mediator (emotion control)</td>
<td></td>
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<td></td>
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<tr>
<td>DV = Emotion control</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Step 2: Learning goal orientation</td>
<td>.17</td>
<td>.06</td>
<td>.28**</td>
<td>.10</td>
<td>.08**</td>
</tr>
<tr>
<td>Effect of emotion control on self-efficacy, controlling for learning goal orientation</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>DV = Self-efficacy</td>
<td></td>
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</tr>
<tr>
<td>Step 2: Learning goal orientation</td>
<td>.11</td>
<td>.08</td>
<td>.12</td>
<td>.21</td>
<td>.05*</td>
</tr>
<tr>
<td>Step 3: Emotion control</td>
<td>.48</td>
<td>.13</td>
<td>.32**</td>
<td>.30</td>
<td>.09**</td>
</tr>
<tr>
<td>Effect of learning goal orientation on self-efficacy, controlling for emotion control</td>
<td></td>
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<tr>
<td>DV = Self-efficacy</td>
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<tr>
<td>Step 2: Emotion control</td>
<td>.48</td>
<td>.13</td>
<td>.32**</td>
<td>.29</td>
<td>.13**</td>
</tr>
<tr>
<td>Step 3: Learning goal orientation</td>
<td>.11</td>
<td>.08</td>
<td>.12</td>
<td>.30</td>
<td>.01</td>
</tr>
</tbody>
</table>

Note. N = 109, * p < .05, **p < .01.
Although not a test of mediation, comparison of the correlations between emotion control and task performance in the high structure + error encouragement instructions condition and in the high structure + no instructions condition was suggestive of an interactive effect of emotion control and effect of instruction (see Tables 7 and 8). As a post-hoc analysis, this interaction was tested on task performance. The interaction was marginally significant for immediate task performance, $F(1, 104) = 3.53, p = .063$, partial $\eta^2 = .07$; and was significant for delayed task performance, $F(1, 104) = 7.67, p = .007$, partial $\eta^2 = .03$. The interactions were plotted using the 25th and 75th percentiles of emotion control. Figures 8 and 9 display a two-way cross-over interaction for immediate and delayed task performance, respectively. These figures show that, for trainees high in emotion control, task performance was better in the high structure + error encouragement instructions condition than in the high structure + no instructions condition. Whereas for trainees low in emotion control, task performance was better in the high structure + no instructions condition than in the high structure + error encouragement instructions condition.

In summary, when error encouragement instructions were incorporated in the training, the relationship between learning goal orientation and self-efficacy for Access retention was fully mediated by emotion control. Emotion control did not mediate this relationship when testing the two high structure training conditions. However, a cross-over interaction was found for the effect of instruction and emotion control on task performance, in the two high structure training conditions.
Figure 8. Emotion control x effect of instruction interaction for immediate task performance

Figure 9. Emotion control x effect of instruction interaction for delayed task performance
Timing Data

As the practice tasks were self-paced, timing data was collected to test for differences across training conditions.

The mean training time for low structure + error encouragement instructions condition was 41 min ($SD = 18.6$), compared to 29 min ($SD = 11.2$) in the high structure + error encouragement instructions condition, and 30 min ($SD = 12.3$) in the high structure + no instructions condition. Controlling for computer experience, the difference was significant: $F(2, 154) = 20.56, p < .001$, partial $\eta^2 = .21$.

In addition, after controlling for computer experience, there was a strong effect of age on training time: $F(1, 155) = 21.09, p < .001$, partial $\eta^2 = .12$. A correlation analysis found a high positive correlation between age and training time ($r = .44, p < .001$), indicating that older learners took longer to complete the training.

Attitude Towards Training

Attitude towards training was assessed after the immediate task performance test and after the delayed task performance test. The means and standard deviations for attitude towards training across all conditions and for each condition are reported in Table 11. The means show a generally positive attitude towards the training: around 6 (on a 7-point scale) on the immediate measure, and a little over 5 on the delayed measure. Controlling for computer experience, no effect of condition on attitude towards training was detected on the immediate measure: $F(1, 157) = 1.73, p = .181$; or on the delayed measure: $F(1, 157) = .48, p = .621$. However, examination of the means shows a slight trend for a more positive attitude towards training in the low structure + error
encouragement instructions condition, followed by the high structure + error
encouragement instructions condition, with the least positive mean attitude towards
training in the high structure + no instructions condition.

Table 11. Means and standard deviations for immediate and delayed measures of attitude
towards training, overall and by condition

<table>
<thead>
<tr>
<th>Condition</th>
<th>Immediate Measure</th>
<th>Delayed Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$</td>
<td>$SD$</td>
</tr>
<tr>
<td>Overall</td>
<td>5.97</td>
<td>.88</td>
</tr>
<tr>
<td>HE</td>
<td>6.02</td>
<td>.95</td>
</tr>
<tr>
<td>HN</td>
<td>5.80</td>
<td>.95</td>
</tr>
<tr>
<td>LE</td>
<td>6.07</td>
<td>.81</td>
</tr>
</tbody>
</table>

*Note.* HE = high structure + error encouragement instructions, HN = high structure + no
instructions, LE = low structure + error encouragement instructions.
Overall $N = 161$, HE $N = 57$, HN $N = 52$, LE $N = 52$.

Table 6 shows the correlations between attitude towards training and study
variables. It is interesting to note that trainee's attitude towards training at the end of the
study (delayed measure) is positively correlated with their self-efficacy for retention ($r = .454, p < .001$),
but not significantly related to actual performance ($r = .091, p = .251$).
This suggests that the affective outcome of self-efficacy may be of greater importance in
judgments of whether the training was effective and enjoyable than demonstrated task
performance.
DISCUSSION

This study investigated the components of error management training from a resource allocation perspective. The effects of varying the type of instructions given during training, and the effects of varying the level of training structure, were evaluated using computer training and a community sample.

Overall, the low structure + error encouragement instructions condition resulted in the best performance, followed by the high structure + error encouragement instructions condition, and finally the high structure + no instructions condition. This study found no evidence for the mediating role of self-regulatory processes between the cognitive ability, or learning goal orientation, and task performance relationship, although emotion control was found to fully mediate the relationship between learning goal orientation and retention self-efficacy.

Effect of Instruction

From a resource allocation perspective, errors typically elicit stress and frustration (Brodbeck et al., 1993), which draw resources away from the task at hand. Instead of focusing on the training task, trainees’ limited attentional resources may be diverted to performance anxiety and off-task thoughts. The error encouragement instructions advised trainees that making mistakes was a natural part of the learning process, that errors promoted effective learning, and that they should attend to the computer screen and watch for changes in the event of an error. It was expected that older learners and low ability learners would benefit from the error encouragement instructions, even in highly
structured training. What emerged from the data was a more complex pattern of performance, dependent on both age and cognitive ability.

The primary finding of interest was the three-way interaction between age, cognitive ability, and effect of instruction, on task performance in high structure training. It was of particular note that these interactive effects were evident not only in immediate task performance, but more importantly, that they were sustained, and the trends suggested in some cases strengthened, over a retention interval. A similar overall pattern of interaction was observed on task performance both immediately and after a one week delay.

For younger trainees with medium to high levels of cognitive ability, there was little or no effect of error encouragement instructions on task performance. But younger trainees with low levels of cognitive ability benefited considerably by being told repeatedly that errors were good opportunities for learning. For middle aged trainees, the error encouragement instructions increased performance on the immediate test regardless of level of cognitive ability, although the effect was stronger for medium-ability trainees. However, a remarkable performance boost was observed for trainees in the middle-age group with either low or medium levels of cognitive ability after a retention interval. That a seemingly minor, and easy to implement, manipulation could result in such a striking difference in performance – and one that becomes more prominent over time – is surprising, and useful from an applied perspective. For older trainees, error encouragement instructions strengthened performance for those with medium to high levels of cognitive ability, and the beneficial effect on performance appeared to be stronger after a delay. However, for older trainees with lower levels of cognitive ability,
there was a slight detrimental effect of the error encouragement instructions on task performance.

It was also noteworthy that when computer experience was controlled, older high ability participants could match the task performance scores of younger high ability participants, if the older participants had the error encouragement instructions. Typically, younger learners outperform older learners (e.g., Charness et al., 1992), but the results reported here demonstrate that older learners have the capability to perform just as well as younger learners, when they have the right instructions and computer experience is controlled.

Taken together, these findings illuminate the importance of providing instructions that encourage middle-aged trainees with low to medium levels of cognitive ability, older trainees with medium to high levels of ability, or younger trainees with low levels of ability, to make errors and learn from them. It is also informative to note that the error encouragement instructions were provided only during training – not at test. That some trainees in the error encouragement instructions condition continued to outperform those who did not receive instructions, even after a delay, suggests that these instructions teach trainees effective strategies to handle errors during the test, and that these strategies persist over time.

Those who benefited most from the error encouragement instructions included low ability young trainees, low and medium ability middle-aged trainees, and medium to high ability older trainees. This pattern of differences suggested that age-related changes in cognitive ability may be affecting training performance.
The measure of cognitive ability used in this study is the Wonderlic test, which taps both the fluid and crystallized components of ability. Typically, the components of fluid ability associated with learning (working memory and the processing of novel information) decline over the lifespan (Horn & Cattell, 1967), and it is these fluid components of ability that are associated with attentional resources in the resource allocation framework. It is conceivable that the groups whose performance increased markedly as a result of the error encouragement instructions were those with lower levels of fluid ability. Young adults tend to have relatively high levels of fluid ability, so only those who are in the lowest ability group, as assessed by the Wonderlic, benefit from the error encouragement instructions. Middle-aged adults will have already experienced a reduction in fluid ability. Therefore, even at medium levels of ability (as well as low levels), the error encouragement instructions have a strong effect by preventing the supply of resources (which is further limited by age-related declines in fluid ability) being diverted to off-task concerns. Among older trainees, fluid ability will have sharply decreased, and this reduction in resources should be evident in trainees with medium and even high levels of cognitive ability. In this study, older trainees have been shown to benefit from the error encouragement instructions only at medium and high levels of cognitive ability. Older trainees with low ability (as indexed by the Wonderlic) demonstrated a decrement in performance with the error encouragement instructions. This could be due to insufficient attentional resources, or fluid ability, to engage in the strategies advocated in the error encouragement instructions, in addition to focusing on the task demands. That is, older low ability trainees may have been overwhelmed by the
combination of a new and complex task plus additional instructions, since they had very few resources to devote to the task alone.

Younger trainees with high levels of ability also demonstrated a decrement in performance with the error encouragement instructions. It is possible that they found the error encouragement instructions distracting or annoying, since they had sufficient resources to meet the task demands. The instructions were presented repeatedly throughout the training, and so could be regarded as a nuisance if they were unnecessary.

Future studies could test this speculation by replicating the three-way interaction found here, but replacing the Wonderlic test with test batteries that measure fluid and crystallized ability directly. This was not possible in the current study due to time constraints.

**Effect of Structure**

When error encouragement instructions were provided, low structure training resulted in better immediate task performance than high structure training. This finding is consistent with the notion that the opportunity to make mistakes during training, and to develop strategies to deal with errors, is beneficial for learning. Previous research has found that errors provide useful feedback (Lorenzet et al., 2005), and promote effective strategies for learning such as exploratory behavior and metacognitive activity (Dormann & Frese, 1994; Ivancic & Hesketh, 2000; Keith & Frese, 2005).

In addition to the opportunity to learn from errors in low structure training, there was also greater correspondence between the training and the test tasks than in high structure training. In low structure training, trainees were given a practice problem, along
with very limited guidance on how to complete the task. They were required to analyze the question and devise a way to obtain the information specified in the problem. In high structure training, trainees were given the same practice problem, but they simply had to follow the step-by-step instructions to obtain the correct answer. Trainees in both conditions completed the same test, which required analysis of the question, and generation of a solution that would obtain the necessary information. It is clear that the processes used in the low structure training have greater overlap with the processes necessary for successful test performance than do the processes used in the high structure training. Therefore, the superior effect of low structure training in an immediate performance test is in line with the principle of transfer-appropriate processing (Morris et al., 1977).

However, this benefit for task performance was not found to persist over time, nor influence knowledge structures or self-efficacy for knowledge retention. The mean scores for these training outcomes show that there was a trend for low structure training to result in better delayed task performance, higher levels of self-efficacy, and greater similarity to an expert's knowledge structure, but the differences were not statistically significant. It is possible that there was insufficient power to detect an effect. A power analysis indicated that there was power of .71 to find a medium-sized effect of structure ($d = .5$), and that 64 participants would be needed in each condition to reach power of .80.

If not due to a lack of power, the absence of a significant main effect after a one-week delay is somewhat surprising. Given the purported cognitive benefits of making errors, it was expected that trainees in the low structure condition would develop a richer understanding of the database software, as well as better strategies for error detection and
hypothesis-testing, that would enable better transfer performance. Indeed, the large body of literature on adding difficulty during training to enhance transfer performance would go further and predict a stronger effect after a delay (Schmidt & Bjork, 1992). Relevant research in the error management training domain reported that the improved performance effects observed in low structure + error encouragement instructions versus high structure + no instructions training were stable over time (Heimbeck et al., 2003). However, they did not compare the effect of structure in the presence of error encouragement instructions. Heimbeck et al. (2003) assumed, perhaps, that it was pointless to test the high structure + error encouragement instructions condition, since there should be no error commission in the high structure training, rendering the error encouragement instructions nonsensical. On the contrary, the results of the current study highlight the importance of the error encouragement instructions, even in high structure training, but only for trainees of a particular age and ability level. When Heimbeck et al. (2003) compared the effect of structure between a high structure + no instructions condition and a low structure + no instructions condition, they found no differences in immediate or delayed performance. Although not significant, Heimbeck and colleagues did find a trend toward slightly better performance in the low structure training, which is in line with the results of the current study.

Other main effects found when comparing the high structure + error encouragement instructions condition with the low structure + error encouragement instructions condition include those of cognitive ability and learning goal orientation on training outcomes. Cognitive ability demonstrated a typical strong main effect on training outcomes, with trainees high in cognitive ability performing better on immediate and
delayed task performance, as well as possessing knowledge structures that were more similar to an expert's, compared to trainees low in cognitive ability. However, the effect of cognitive ability appeared to be limited to more cognitive assessments of learning, as ability did not affect self-efficacy for Access knowledge retention. From a resource allocation perspective, high cognitive ability indicates the availability of more attentional resources to devote to learning. These resources give trainees a greater capacity to attend to training, process new information, use strategies to enhance learning, and deal with the demands of new and difficult tasks (Kanfer & Ackerman, 1989). The computer training used in this study was new and challenging, and performance was dependent on trainees' level of ability. Previous research has found an effect of cognitive ability (Gully et al., 2002), but none was detected here. This is likely due to lack of power, as the positive correlations between cognitive ability and self-efficacy for retention are suggestive of a trend in the expected direction (see Tables 7, 8, and 9). A power analysis indicated that there was power of only .59 to detect a correlation of .3 in this study.

A main effect of learning goal orientation was found on self-efficacy and on knowledge structures. Trainees high on learning goal orientation reported higher self-efficacy for Access retention, but had knowledge structures that were less similar to that of an expert, than trainees low on learning goal orientation. The effect on self-efficacy will be discussed below in the context of a mediated relationship. The negative effect of learning goal orientation on knowledge structures may be due to demand characteristics. It is possible that participants inflated their reports of learning goal orientation, as the traits associated with learning goal orientation are beneficial in a training situation. This
may account for the non-significant relationship with task performance, and the negative relationship with knowledge structures.

**Mediating Role of Self-Regulatory Processes**

Emotion control fully mediated the relationship between learning goal orientation and self-efficacy for retention of Access knowledge in the low structure + error encouragement instructions and the high structure + error encouragement instructions conditions. Learning goal orientation is a dispositional tendency that is characterized by a desire to extend one’s skill repertoire and to master those skills, a preference for challenging tasks, persistence in the face of failure, and motivation to try harder, even on difficult tasks. Emotion control is a self-regulatory process that is characterized by a focus on the task, a lack of distraction by negative emotions or performance anxiety, and composure in the face of errors. Although some facets of learning goal orientation may appear to overlap with emotion control, they are regarded as separate constructs, the former being a broader dispositional tendency, and the latter being a specific strategy adopted during task engagement.

Theoretically, learning goal orientation has clear benefits for training, particularly in relatively complex computer training. In the current study, the beneficial effects of learning goal orientation on self-efficacy were fully mediated by emotion control. This finding is consistent with the view that individuals high on learning goal orientation do not get distracted by negative emotions or performance anxiety when they make errors, and this contributes to a confidence in their ability to retain, or relearn if necessary, the skills they acquired during training.
The hypothesized mediating effects of self-regulatory processes between the substantial cognitive ability-training performance relationships were not detected in this study. Somewhat surprisingly, cognitive ability was not related to any of the measures of self-regulation. From a resource allocation perspective, it would be expected that cognitive ability, as a measure of available attentional resources, would be associated with the use of processes and strategies that are effective for learning. But, other than the mediating role of emotion control on the learning goal orientation-self-efficacy relationship described earlier, the current study did not find evidence that the distal predictors operated on training outcomes via any of the self-regulatory processes measured here. It could be that there was insufficient power to detect an effect, or that the scales used to measure these processes failed to capture the construct. For example, the metacognitive activity scale may be more suited to measuring metacognition across longer training programs, or in contexts which allow for greater variation in metacognitive activity, such as a semester-long college course (Campbell & Beier, 2006). If not due to power or measurement issues, these results suggest that there may be other mechanisms, not measured in this study, that are important mediators between stable individual differences and training performance.

One related finding was the cross-over interaction of effect of instruction and emotion control in predicting task performance. For trainees high in emotion control, task performance was better in the high structure + error encouragement instructions condition than in the high structure + no instructions condition; whereas for trainees low in emotion control, task performance was better in the high structure + no instructions condition than in the high structure + error encouragement instructions condition. Although this is not
evidence for mediation of task performance, this interaction does support the importance of emotion control as a self-regulatory process that affects skill-based performance, as well as the more affectively-oriented self-efficacy criterion. This finding suggests that emotion control skill may be an important prerequisite for error encouragement instructions to be effective. It is also in line with previous research that reported emotion control fully mediated the relationship between training condition and adaptive transfer in an error management training study (Keith & Frese, 2005).

**Summary of Findings**

In summary, the current study investigated the effect of error encouragement instructions, and the effect of structure, on training outcomes. Examination of the effect of training instructions revealed an age x cognitive ability x type of instruction interaction on immediate and delayed task performance in computer training. Error encouragement instructions affected training outcomes under high structure training conditions, but their effects depended on age and level of cognitive ability. Error encouragement instructions were beneficial for performance when the trainees were younger with low cognitive ability, middle-aged at any ability level (but particularly at low to medium levels), and older with medium to high cognitive ability. The instructions had little effect on younger trainees with medium ability, and they had a slight detrimental effect on younger trainees with high ability and on older trainees with low ability. It is possible that these different patterns of performance were the result of age-related declines in the fluid ability component of general cognitive ability, but that cannot be confirmed with these data
since the Wonderlic test used in this study captures both fluid and crystallized components of cognitive ability.

The effect of structure was also examined. When tested immediately after training, task performance was superior following low structure training to performance following high structure training. This enhancement can be accounted for by the cognitive benefits of dealing with errors, and by the principle of transfer-appropriate processing, as there was a greater degree of overlap in the cognitive processes engaged during training and during test in the low structure condition. However, the beneficial effect of low structure was not found to persist over time.

Across all three training conditions, superior task performance was observed in the low structure + error encouragement instructions condition, followed by the high structure + error encouragement instructions condition. However, training was approximately 40% longer, on average, in the low structure + error encouragement instructions condition than in the high structure + error encouragement instructions condition. In addition, the benefit for immediate task performance in the low structure + error encouragement instructions condition compared to the high structure + error encouragement instructions condition (partial $\eta^2 = .04$), dropped to non significant levels (partial $\eta^2 = .01$) after the retention interval.

Finally, self-regulatory processes were tested as potential mediators of the relationships between distal predictors and training outcomes. This study found that emotion control fully mediated the relationship between learning goal orientation and self-efficacy for retention of Access knowledge in the error encouragement instructions conditions. Further evidence for the importance of emotion control in training was found
in a two-way interaction of effect of instruction and emotion control for task performance. Trainees high in emotion control performed better in the high structure + error encouragement instructions condition than in the high structure + no instructions condition; whereas trainees low in emotion control performed better in the high structure + no instructions condition than in the high structure + error encouragement instructions condition.

Implications

These data suggest that understanding the relationships between training design and transfer performance is a complex endeavor, and is one that must take account of key individual difference variables, particularly age and cognitive ability. Given demographic projections indicating that there will be an older workforce in need of retraining, research on effective computer training design for older learners has been described as “imperative” (Chillarege et al., 2003, p. 370). This research contributes to the existent literature on training design that improves performance for older learners.

Theoretically, these results can be understood within the resource allocation framework, using the availability of cognitive resources as a general approach to understanding training performance. However, no evidence was found in this study for the mediating roles of metacognitive activity or self-efficacy between distal predictors and training outcomes. It is possible that different self-regulatory processes operated during this training program, that the measures of these constructs were inadequate, or that there was insufficient power to detect effects.

The results presented here highlight the value of transfer-appropriate processing as a general principle to guide optimal training design, and support the notion that adding
difficulty during training can boost performance. However, the results of this study support the addition of a caveat to these general cognitive guidelines: that the implementation of these principles should be considered in conjunction with an assessment of trainee individual differences.

On a more practical level, these results have exciting implications for training practitioners. First and foremost, trainers should have a clear understanding of their target audience, and adapt the training program to optimize performance based on trainee age and ability level. These findings illuminate the importance of providing instructions that encourage middle-aged trainees with low to medium levels of ability, older trainees with medium to high levels of ability, or younger trainees with low levels ability, to make errors and learn from them. It was particularly promising that these effects were not only sustained, but actually increased after a retention interval for some middle-aged and older trainees, as improving transfer performance is the primary goal of training programs.

However, trainers should recognize that the error encouragement instructions may not enhance performance for younger trainees with medium levels of ability, and be aware that they may even be detrimental to performance for younger trainees with high ability and older trainees with low ability. Also, it should be noted that, as a trainer, it can be difficult to let people struggle and make mistakes in low structure training, and that trainees may expect a high degree of assistance from the trainer. It is often much easier to intervene and show trainees how to perform the training tasks. But this practice does not encourage the independent thinking nor develop the error detection skills necessary for effective transfer of training.
Given the sometimes drastically different patterns of performance in different age x ability groups, it would be prudent to conduct a brief assessment of key individual differences, if feasible. Alternatively, error encouragement instructions could be used for all trainees in a mixed group, since the gain in performance for the majority of age and ability groups may offset the slight cost to high ability younger trainees (who tend to have the best performance across groups, even in sub-optimal conditions) and low ability older trainees (who may have difficulty in most training interventions, relative to other learners).

The interaction of emotion control and effect of instruction on task performance suggests that being able to control negative reactions during training is an important component of successful performance in the high structure + error encouragement instructions condition. Since emotion control is regarded as a skill, rather than a stable individual difference, it should be malleable. Future research could examine the effect of an intervention to improve emotion control, which may augment the benefits observed in the high structure + error encouragement instructions condition.

Customizing training to optimize an individual’s transfer performance has greater feasibility in the burgeoning field of e-learning. E-learning refers generally to the delivery of any learning or training by electronic means, and includes web-based and computer-based learning, as well as training that involves digital media. The computer training in the current study was primarily conducted at the individual level – trainees did not consult each other, and there were no sections involving group instruction. The only personalized interventions involved experimenters pointing out information that may have been helpful in the minimal manuals, but this could perhaps be transferred to an e-
learning environment by incorporating prompts if trainees have explored the program and do not know how to proceed. In an e-learning environment, trainees could be simply administered a questionnaire in which they provided their age, and if possible, some indication of ability. This information could then be used to increase the probability of successful transfer, by customizing the training to the trainee.

Another interesting implication of these results relates to age and training time. As found in the current study, the time required for trainees to process training materials typically increases with advancing age (Charness et al., 2001; Sterns & Doverspike, 1989), but older trainees can master material, given sufficient time (Meyer, 1987). One of the most effective ways to scaffold learning in older trainees is to allow self-paced learning (Callahan, Kiker, & Cross, 2003), but this manipulation usually results in increased training time for older learners. In addition, there is some evidence that older trainees benefit from high structure (Ackerman & Beier, 2006). The high structure + error encouragement instructions manipulation in the current study is an example of how self-pacing can be combined with high structure, which potentially reduces the time necessary for training compared to a low structure training condition.

**Limitations & Suggestions for Future Research**

This study used a community sample, with greater variance in age, ability, and perhaps goal orientation, than typical undergraduate samples. This enabled investigation of variation in performance patterns that was related to these important individual differences. The goal of this study was to generalize the results to a working population, and there was an enormous range of self-reported occupations in the sample. However,
one potential limitation is that the sample may be atypical in that it over-represented individuals with a keen interest in learning new software. Although anecdotally, some participants reported interest in developing computer skills, whereas others commented on the financial compensation the study offered. Another potential limitation of the sample is that it may have over-represented unemployed individuals. Sixteen out of 161 participants (10%) reported being unemployed, a homemaker, or a stay at home mom or dad. A third potential limitation of the sample is that there was a large range in ability, and the sample may have included individuals who would not typically be trained on relatively complicated database software. Future studies could target employed samples at occupational levels that would be expected to undergo training on relatively complex software.

This study found evidence for the importance of age, cognitive ability, and goal orientation as variables that affect learning. Future research could test other potentially important individual differences. For example, the personality traits of openness to experience and conscientiousness have been associated with positive learning outcomes (Barrick & Mount, 1991), and have been shown to interact with training instruction (Gully et al., 2002). These traits are easily assessed with a brief scale, and if interactive effects were found in error management training, they could be built into a customized training program.

Perhaps the greatest limitation of the study is that only three of the four cells in a 2 (structure: high vs low) x 2 (instructions: error encouragement vs none) design were tested. This allowed for tests of the effect of structure, controlling for instruction, and for tests of the effect of instruction, controlling for structure. But the effect of structure was
only assessed under error encouragement instruction conditions, and the effect of instruction was only assessed under high structure conditions. Future research could combine all four cells in a single study, by adding a low structure + no instructions condition.

This study failed to find an effect of metacognitive activity on learning, despite other studies showing a clear relationship (e.g., Ford et al. 1998; Schmidt & Ford, 2003). However, metacognitive activity may be less important in high structure training conditions, which necessarily involve less learner control. Indeed, the only statistically significant relationship with metacognitive activity in the current study was with a training outcome in the low structure condition. In addition, the scale was administered at the end of training, rather than during the training program. Metacognition has been examined in error management training using a think-aloud protocol (Keith & Frese, 2005), which may offer a more accurate, online assessment of metacognitive activity in future studies.

The current study used a relatively complex training task. It is likely that task complexity is an important moderator of the effects reported here, since complexity will affect the attentional demands of the task. Future research could vary the level of task complexity and assess patterns of performance among trainees with different levels of cognitive resources.

Finally, due to time constraints, a brief measure of cognitive ability was used that combines the contributions of both fluid and crystallized ability. Future studies could include test batteries that measured fluid and crystallized ability separately, which would
allow a more fine-grained analysis of which abilities are important for learning in different training situations.

Conclusion

In conclusion, this study tested the effects of the structural and instructional components of error management training on multiple training outcomes. Rather than use a student sample, these effects were tested on a community sample using computer software training, in order to generalize the results to typical training in a working population. An age x cognitive ability x type of instruction interaction on task performance was detected that persisted over time, and a main effect of structure on task performance was detected that did not persist over time. These results were interpreted within a framework of resource allocation and cognitive principles of transfer.

Taken together, the results of the current study suggest that understanding training and transfer performance is complex, and that key individual differences should be considered when selecting training designs for optimal transfer. The results have clear implications for training practice, in that performance of older trainees with medium to high levels of ability, middle-aged trainees with low to medium levels of ability, and younger trainees with lower levels of ability, can be substantially enhanced simply by encouraging trainees to make mistakes and feel positive about the benefits of errors on learning.
REFERENCES


Chen, G., Casper, W. J., & Cortina, J. M. (2001). The roles of self-efficacy and task complexity in the relationships among cognitive ability, conscientiousness, and


Appendix A  Example screen and script from training presentation

Designing a Totals Query

Click total icon to display Total row

Click in Total row and select calculation

Run the query

Question: What is the average salary in each country?

"First, you add the Country and Salary fields to the query design. Turn on the totals function by clicking on the totals icon on the toolbar. This will display the "total" row in the design view table, above the sort row. Here, we want to know average salary, so we would select average from the drop down menu in the Salary column. Then run the query by clicking the run icon on the toolbar.

Remember that you must do the calculation in the relevant column, and on numeric data, such as salary, not on text data, such as country."
**Access Manual: How To...**

**Design and Run a Select Query**

**Purpose:** To display a subset of your data, by selecting certain fields/columns and using criteria.

**How To:**

Check that the “Queries” tab on the left of the database window is highlighted and create a query in design view (do not use the wizard).

In Design View, select the table you want to query, begin adding columns and specifying criteria (if you have any), then Run the query.

**TIP:** Add only one table (the one you want to query) in query Design View. If you add more than one table by mistake, right-click on it and select “Remove table.”

**TIP:** If your query won’t run, check your criteria are in the correct format (see “Use Criteria” section below)

**TIP:** If your query dynaset has no records in it, check that:
- any text criteria is written EXACTLY as it appears in the data table
- format of criteria is correct (e.g., #12/2/2004#)

********************************************************************************

**Sort Records**

Find the sort row in the Design View box.
Click in the sort row in the field you want to sort and select your sort from the drop-down menu.
CHECK RESULTS OF A QUERY AND MODIFY QUERY DESIGN

How To:
Switch views between Datasheet and Design view.

**TIP:** You don’t need to start a select query from scratch if you want to make changes – just switch between datasheet and design views.

SAVE FILES
To save a QUERY: Go to File/Save As. Save as "test#", and as a query, then click OK.

USE AND/OR RULES

AND RULE
Same row = AND rule.

- If you put multiple criteria on the SAME ROW, you will find records that meet ALL of the criteria in that row (e.g., if “London” and 1999 are in the same row, only records from BOTH London AND 1999 will be included in the dynaset.)

OR RULE
Different row = OR rule.

- If you put multiple criteria on DIFFERENT ROWS, then AT LEAST ONE of the criteria must be true for the record to be included in the dynaset (e.g. if “London” and 1999 are on different rows, records from London OR 1999, or both, will be included.)
USE CRITERIA

**Purpose**: To select a specific subset of your data in query design (e.g., only records between certain dates).

**How To**: Use in the criteria row(s) under the relevant column in query design.

**TIP**: Make sure your criteria are in the RELEVANT column (e.g., Ship City names are in the Ship City column – not Ship Country or Employee)

TEXT CRITERIA

Put text in quotation marks, e.g., "London"

**TIP**: Text in quotation marks (e.g., names) should be EXACTLY as it appears in the data table. CHECK how it is written in the data table.

DATE CRITERIA

Put dates between pound signs and in this format: #1/3/2000#

Do not use quotation marks with dates.

**TIP**: You can use date criteria with all of the Operators (see table below)

**TIP**: If you cannot see all of your criteria, make the columns wider by clicking and dragging the edge – it is easier to spot small mistakes in the format that way (e.g., forgetting to put # before AND after each date)

OPERATORS (like math functions)

<table>
<thead>
<tr>
<th>Format</th>
<th>Meaning</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;</td>
<td>Less than or before</td>
<td>&lt;20</td>
</tr>
<tr>
<td>&gt;</td>
<td>Greater than or after</td>
<td>&gt;4</td>
</tr>
<tr>
<td>&lt;=</td>
<td>Less than or equal to</td>
<td>&lt;=20</td>
</tr>
<tr>
<td>&gt;=</td>
<td>Greater than or equal to</td>
<td>&gt;=4</td>
</tr>
<tr>
<td>Between x And y</td>
<td>Between value x and value y</td>
<td>Between #12/1/2004# And #5/2/2006#</td>
</tr>
<tr>
<td>&lt;&gt;</td>
<td>Not equal to</td>
<td>&lt;&gt;10</td>
</tr>
</tbody>
</table>
Design and Run a Totals Query

Purpose: To perform calculations on data in a field: select from Sum, Average, Minimum/Maximum Values, Standard Deviation, Variance, First/Last Values, or Count # Records.

How To: Add the “totals” row \( \Sigma \). Select a calculation from the drop-down menu.

TIP: Only include the columns necessary for your calculation. If you don’t get the values you want, there are probably too many columns.

Totals Query Options

<table>
<thead>
<tr>
<th>Option</th>
<th>Query returns...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg</td>
<td>Average value of records in field</td>
</tr>
<tr>
<td>Count</td>
<td>How many records</td>
</tr>
<tr>
<td>Sum</td>
<td>Sum/total value of records in field</td>
</tr>
<tr>
<td>First</td>
<td>Value stored in first record</td>
</tr>
<tr>
<td>Last</td>
<td>Value stored in last record</td>
</tr>
<tr>
<td>Max</td>
<td>Highest value in all records</td>
</tr>
<tr>
<td>Min</td>
<td>Lowest value in all records</td>
</tr>
<tr>
<td>StDev</td>
<td>Standard deviation (a statistical measure)</td>
</tr>
<tr>
<td>Var</td>
<td>Variance (a statistical measure)</td>
</tr>
</tbody>
</table>
TROUBLE-SHOOTING

I HAVE MULTIPLE TABLES IN THE DESIGN VIEW...
- You want only one “Orders” table in query design view. Right-click on your extra table and select “Remove table.”

MY QUERY WON’T RUN, EVEN WHEN I CLICK THE “RUN” ICON...
- Check that criteria are in the correct format (see “Using Criteria” section above)

THERE ARE NO RECORDS SHOWING IN THE DYNASET...
- Check that text in quotation marks is exactly as it appears in the data table
- Check the format of criteria is correct (e.g., #12/2/2004#, see “Using Criteria” section above)

THE RECORDS IN MY DYNASET ARE NOT CORRECT...
- Check your criteria are in the correct column (e.g., Ship City criteria in Ship City column)
- Check that text in quotation marks is exactly as it appears in the data table
- Check that criteria are in the correct format (see “Using Criteria” section above)

MY TOTALS QUERY DOESN’T LOOK RIGHT...
- Check that you have included ONLY the columns necessary for your calculation. Remove any extra columns.

HOW DO I MODIFY A SELECT QUERY?
- Switch views between Datasheet and Design view. You can modify in Design view
Appendix C  Example of high structure training practice question

The Shipping Department has requested information on orders going to France and USA on certain dates.

Using the QUERY function, display data on Customer, Freight, Required Date, and Ship Country, in that order. Your dynaset should include the following records:
- Those with Required Dates between 9/1/1996 and 1/1/1997 (inclusive) and that are going to France
- Those with Required Dates between 1/1/1998 and 12/1/1998 (inclusive) and that are going to USA

Instructions

1. Follow on-screen instructions to open Access (click Continue to open Access)

2. When Access is open, click on the Open File icon , or go to File on the menubar, and click Open.
3. Go to the Desktop, click on the file called "Northwind" (it may be called "Northwind.mdb") and click Open.
4. You may see a Security Warning. If you do, click Open.
5. The Northwind database will open.
6. Go to the database window and click on the “Queries” tab in the left panel
7. Double-click “Create query in Design view”.
8. When the “Show table” window appears, choose “Orders.”
9. Click “Add”, then “Close” the window. A small “Orders” box will appear in the design view.

10. Double-click on "Customer." This field name will appear in a column in the lower box.
11. Double-click on “Freight”, then double-click on “Required Date”, then double-click on “Ship Country.” These field names will appear as column headings in the lower box.

12. In the “Required Date” column, in the “Criteria” row, type *Between #9/1/1996# and #1/1/1997#.*

13. In the “Ship Country” column, in the “Criteria” row, type “France”.
14. In the "Required Date" column, in the "or" row (below the "criteria" row), type Between #1/1/1998# and #12/1/1998#.

15. In the “Ship Country” column, in the "or" row (below the “Criteria” row), type “USA”.

16. Click the run icon ✉️ to run the query to see your dynaset.

17. You should have 53 records.
18. Your dynaset should look like this:

![Image of P2: Select Query]

19. Save your query: Click on File, and Save As. In the Save As box, save your query to **P2**, and as a query, then click OK.

![Image of Query 1: Select Query]

20. Click on File in the menubar, and Exit to close Access. Please **CLOSE ACCESS ENTIRELY** and return to the training presentation.
Appendix D  Example of low structure training practice question

The Shipping Department has requested information on orders going to France and USA on certain dates.

Using the QUERY function, display data on Customer, Freight, Required Date, and Ship Country, in that order. Your dynaset should include the following records:
- Those with Required Dates between 9/1/1996 and 1/1/1997 (inclusive) and that are going to France
- Those with Required Dates between 1/1/1998 and 12/1/1998 (inclusive) and that are going to USA

Check your results match the criteria in the question.
You should have 53 records.

SAVE your query as P2.

Your dynaset should look like this:

Now please CLOSE ACCESS ENTIRELY and return to the training presentation.
Appendix E  Example of task performance test question

Andrew Fuller (an Employee) has had trouble keeping track of the Required Dates of orders he has taken. He has asked you to provide a dynaset showing the Customer, Required Date, Ship City, and Ship Country (in that order) for orders he has taken that are going to Rio de Janeiro, Marseille, Torino, Graz, Seattle, or Madrid that have Required Dates after 1996. He would like the data presented with the earliest Required Date first.

What is the earliest Required Date?

Answer: __________________________________________________________

What is the Required Date for the order going to France?

Answer: __________________________________________________________

How many records are returned in this dynaset?

Answer: _________________________________________________________

Please SAVE your file as "test2"
Then CLOSE ACCESS and follow the on-screen instructions.
Appendix F  Example of scoring protocol for task performance

<table>
<thead>
<tr>
<th>Component</th>
<th>Poss. Points</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>6a.</strong> Select Query</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>6b.</strong> Include Order ID column</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>6c.</strong> Include Ship Country column</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>6d.</strong> Include Order Date column</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>6e.</strong> Include Employee column</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td><strong>6f.</strong> Include criterion: &quot;France&quot;</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><strong>6g.</strong> Include criterion: &quot;Germany&quot;</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><strong>6h.</strong> Include criteria: “France” and/or &quot;Germany&quot; in Ship Country column</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td><strong>6i.</strong> Include date criteria:</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>$\geq 12/31/1996$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>or $\geq 1/1/1997$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>or Between $1/1/1997$ and $6/4/1998$ (or latter date could be any date after 6/3/1998)</td>
<td>(1 point for attempted date if incorrect format)</td>
<td></td>
</tr>
<tr>
<td><strong>6j.</strong> Include date criteria:</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>$\geq 11/30/1997$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>or $\geq 12/1/1997$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>or Between $12/1/1997$ and $2/2/2007$ (or latter date could be any date after 6/4/1998) in another row</td>
<td>(1 point for attempted date if incorrect format)</td>
<td></td>
</tr>
<tr>
<td><strong>6k.</strong> Include date criteria (6i and/or 6j) in Order Date column</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td><strong>6l.</strong> Include &quot;France&quot; criterion on same row as $\geq 12/31/1996$ criterion (from 6i)</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td><strong>6m.</strong> Include &quot;Germany&quot; criterion on same row as $\geq 11/30/1997$ criterion (from 6j)</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td><strong>6n.</strong> Correct answer to part 1 (104)</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

**6 Deductions:** Show box unchecked (-1 point)
Appendix G  Attitude towards training scale

1. I liked this Access training.
2. I did not enjoy this Access training. (R)
3. The Access training was effective.
4. I don’t feel like I have learned much from this training. (R)
5. This training could have been better. (R)

(R) denotes reverse-scored item
Appendix H  Structure manipulation check

1. I made some errors during the practice tasks.
2. After looking at the results of a query, I needed to go back and change the criteria in order to make the query work properly.
3. I tried several different options when trying to complete a practice task.
4. I was able to complete the practice tasks on the first try without making any mistakes. *(R)*
5. I needed to make changes to my query design in order to successfully complete a task.
6. I was able to complete the practice tasks without having to experiment with the query criteria. *(R)*

*(R)* denotes reverse-scored item
Appendix I  Computer experience items

1. If you own a computer, please state the number of years that you have owned one.
2. Please estimate the number of hours you spend on a computer on an average day.
3. On a scale of 1 (never used) to 8 (true expert), estimate your level of expertise with Microsoft Word.
4. On a scale of 1 (never used) to 8 (true expert), estimate your level of expertise with Microsoft Excel.
5. On a scale of 1 (never used) to 8 (true expert), estimate your level of expertise with Microsoft Powerpoint.
6. On a scale of 1 (never used) to 8 (true expert), estimate your level of expertise with database software.
7. On a scale of 1 (true beginner) to 8 (true expert), estimate your general level of expertise with computers, compared to the general population.
Appendix J  Histogram of cognitive ability scores

Cognitive Ability

Std. Dev = 7.17
Mean = 25.2
N = 161.00

7.5 12.5 17.5 22.5 27.5 32.5 37.5 40.0
Appendix K  Histogram of immediate task performance

Immediate Task Performance

Std. Dev = 37.88
Mean = 111.5
N = 161.00
Appendix L  Histogram of delayed task performance

![Histogram of delayed task performance]

Delayed Task Performance

Std. Dev = 29.58
Mean = 85.6
N = 161.00
Appendix M  Histogram of similarity to expert knowledge structure

Similarity to Expert's Knowledge Structure

Std. Dev = .09
Mean = .275
N = 161.00
Appendix N  Histogram of self-efficacy for retention of access knowledge

Self-efficacy for Retention of Access Knowledge

Std. Dev = .77
Mean = 3.48
N = 161.00