Sequencing Training Interventions to Promote Self-Regulation, Knowledge, and Adaptive Transfer

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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>List of Tables</td>
<td>v</td>
</tr>
<tr>
<td>List of Figures</td>
<td>vi</td>
</tr>
<tr>
<td>Abstract</td>
<td>vii</td>
</tr>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Method</td>
<td>19</td>
</tr>
<tr>
<td>Results</td>
<td>27</td>
</tr>
<tr>
<td>Discussion</td>
<td>35</td>
</tr>
<tr>
<td>Appendix A: Supplemental Descriptive Statistics</td>
<td>50</td>
</tr>
<tr>
<td>Appendix B: Full Literature Review</td>
<td>52</td>
</tr>
<tr>
<td>References</td>
<td>75</td>
</tr>
</tbody>
</table>
LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1. Means, standard deviations, and intercorrelations of study variables</td>
<td>42</td>
</tr>
<tr>
<td>Table 2. Means and standard deviations of mid-training self-regulatory variables and basic knowledge by early training condition</td>
<td>44</td>
</tr>
<tr>
<td>Table 3. Means and standard deviations of post-training self-regulatory processes and strategic knowledge by late training condition</td>
<td>45</td>
</tr>
<tr>
<td>Table 4. Means and standard deviations of adaptive transfer by training condition</td>
<td>46</td>
</tr>
<tr>
<td>Table 5. Goodness-of-fit statistics for structural equation models</td>
<td>47</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1. Hypothesized model of the effects of early and late training condition on self-regulatory processes, knowledge, and adaptive transfer</td>
<td>48</td>
</tr>
<tr>
<td>Figure 2. Structural equation model results for alternative model with full mediation</td>
<td>49</td>
</tr>
</tbody>
</table>
ABSTRACT

SEQUENCING TRAINING INTERVENTIONS TO PROMOTE SELF-REGULATION, KNOWLEDGE, AND ADAPTIVE TRANSFER

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Changes in the nature of work, such as the shift away from repetitive and well-defined tasks toward increasingly novel and ambiguous tasks, require training programs to prepare trainees to be adaptable. As a result, researchers have examined a variety of training interventions designed to encourage different self-regulatory processes that theory suggests are important for promoting knowledge acquisition and adaptive transfer (e.g., Bell & Kozlowski, 2008). The current study focused on two of these approaches: error management training and prompting strategy regulation. These interventions are based on active learning principles and are theorized to increase adaptive transfer via self-regulation and task knowledge. Despite the growing body of research in this area, this line of research has developed independently from the literature on the nature of knowledge acquisition—despite evidence that self-regulatory processes are differentially beneficial at different stages of knowledge acquisition. As such, the present study was
designed to integrate research on adaptability training interventions with the literature on the nature of knowledge acquisition. The results highlight the importance of considering the timing of implementing training interventions. Specifically, receiving error management training in the first half of training led to higher levels of mid-training emotion control and basic knowledge, while receiving strategy regulation prompts in the second half of training led to higher levels of post-training motivation and strategic knowledge. Additionally, results from mediation analyses suggested that self-regulation processes and knowledge levels fully mediated the relationship between training conditions (early and late training) and adaptive transfer.
INTRODUCTION

Changes in the nature of work, such as the shift away from repetitive and well-defined tasks toward increasingly novel and ambiguous tasks, require employees to be highly adaptable (Ilgen & Pulakos, 1999; Pulakos, Arad, Donovan, & Plamondon, 2000). The criticality of an adaptable workforce has created a greater need for improving training effectiveness in organizations. Training programs cannot prepare trainees for every possible situational contingency they will encounter in the workplace. As such, training needs to focus not only on providing individuals with a repertoire of relevant domain knowledge, but also preparing individuals to apply their knowledge and skills under novel conditions. Although traditional training approaches are beneficial for developing performance under routine conditions, training for performance under novel conditions requires a different approach to instructional design (Hesketh, 1997; Smith, Ford, & Kozlowski, 1997). One recent stream of research has focused on training interventions that increase adaptive transfer via self-regulatory processes (e.g., Bell & Kozlowski, 2008; Keith & Frese, 2005). Self-regulation refers to the processes an individual uses to achieve goal attainment, including controlling the direction and intensity of cognition, affect, and behavior (Kanfer & Kanfer, 1991; Karoly, 1993) and has been identified as a core theoretical construct underlying adaptability (Smith et al., 1997).
This line of adaptability training research has identified several promising interventions and has confirmed the centrality of self-regulatory processes during training for improving adaptive transfer (e.g., Bell & Kozlowski, 2008; Keith & Frese, 2005). However, much of this research has emerged separate from the literature on the nature of knowledge and skill acquisition. Most learning models describe knowledge acquisition as being characterized by different stages of learning (Anderson, 1982; Fitts & Posner, 1967; Schneider & Shiffrin, 1977), and self-regulatory processes have been shown to be differentially beneficial across these stages (Kanfer & Ackerman, 1989). This suggests that integrating self-regulatory interventions into training programs requires a dynamic perspective—one that takes into account which self-regulatory processes are important across the different stages of learning. As such, the goal of this study is to integrate the adaptability training literature with research on the nature of knowledge acquisition. Specifically, this study compares the effects of different sequences of self-regulatory training interventions on self-regulation, knowledge, adaptive transfer. The findings from this study contribute to the self-regulation and adaptability literatures by clarifying the relative importance of different self-regulatory mechanisms across different stages of knowledge acquisition as well as informing theory development on the role of self-regulation and knowledge acquisition in adaptability training.

The following section presents an overview of adaptability, including the challenges of designing training to promote adaptive transfer. Then, two training interventions (error management training and prompting strategy regulation) that have received theoretical and empirical support for increasing adaptive transfer are presented
with an emphasis on the mediating mechanisms—self-regulation and knowledge. Finally, the nature of knowledge acquisition is reviewed and integrated with research on training for adaptability.

Training for Adaptability

Although many definitions of adaptability have been put forth in the literature (e.g., Banks, Bader, Fleming, Zaccaro, & Barber, 2001; Chan, 2000; LePine, Colquitt, & Erez, 2000; Ployhart & Bliese, 2006; Pulakos et al., 2000; White et al., 2005), these definitions all tend to agree that adaptability reflects a functional response in the face of changed environmental circumstances. As suggested by this definition, adaptability does not occur under routine conditions, but rather in response to, or anticipation of, novel or changed conditions (Ployhart & Bliese, 2006; White et al., 2005). Additionally, changing one’s response based on environmental conditions does not guarantee adaptability. Rather, the response must be functional—restoring the fit between an individual’s behaviors and the changed environmental circumstances (Banks et al., 2001; Chan, 2000; White et al., 2005). In describing the nature of adaptability, Chan (2000) noted that in situations requiring adaptability the “established and routine behaviors which were successful in the ‘old’ situations prior to the creation of new problems become irrelevant, ineffective, suboptimal, or less successful in the ‘new’ situation” (p. 6). This presents a rather unique training challenge as most training paradigms focus on building expertise by automating a correct set of behaviors that are considered optimal under routine operating conditions (Hesketh, 1997; Kozlowski, 1998).
In understanding this training challenge, research has examined the nature of expertise. Specifically, researchers have distinguished between two types of experts: routine and adaptive (Hatano & Inagaki, 1986; Hatano & Osawa, 1983; Holyoak, 1991; Kozlowski, 1998). Routine experts maintain a high degree of procedural efficiency in their domain (Hatano & Inagaki, 1986) and can perform quickly and accurately under a fixed set of operational parameters (Kozlowski, 1998). However, routine expertise can be a liability in dynamic work environments (Hesketh, 1997). Specifically, when operational parameters change—creating novel conditions—routine expertise can hinder performance as individuals may fail to recognize that changes in operational parameters have rendered their performance approach ineffective (Kozlowski, 1998; Smith et al., 1997; Sternberg & Frensch, 1992). These types of novel conditions require individuals to have adaptive expertise—exhibiting the core performance efficiencies of routine experts as well as the willingness and ability to detect environmental changes and modify their performance strategies (Hatano & Inagaki, 1986; Holyoak, 1991; Kozlowski, 1998).

Adaptive expertise is characterized by a deep understanding of which concepts in a domain are connected as well as how and why concepts are connected (Holyoak, 1991; Kimball & Holyoak, 2000; Kozlowski, 1998; Smith et al., 1997). This facilitates adaptive experts’ ability to detect relevant environmental changes and approach the situation from a different perspective—often drawing from their knowledge base to create new performance strategies under novel conditions (Holyoak, 1991; Kimball & Holyoak, 2000; Kozlowski, 1998; Smith et al., 1997).

Within the training domain, the development of adaptability skills is
operationalized through successful adaptive transfer (e.g., Bell & Kozlowski, 2008; Ivancic & Hesketh, 2000; Keith & Frese, 2005, 2008). Ivancic and Hesketh (2000) defined adaptive transfer as “using one’s existing knowledge base to change a learned procedure or to generate a solution to a completely new problem” (p. 1968). Under conditions requiring adaptive transfer, trainees must adjust their performance strategies to compensate for changes in the structural features of the task (Smith, 1996).

Successful adaptive transfer does not imply the same level of experience with the training domain as adaptive expertise (estimates suggest that achieving expert level performance in a domain requires thousands of hours of practice; Ericsson & Charness, 1994). However, the theoretical difference between adaptive expertise and routine expertise is the same as the difference between adaptive and analogical transfer (Ivancic & Hesketh, 2000; Smith et al., 1997). While analogical transfer refers to the routinized application of a learned procedure, adaptive transfer implies that the routinized application is not sufficient given the changed parameters and that successful transfer requires the trainee to modify the learned procedures (Ivancic & Hesketh, 1995/1996, 2000; Smith et al., 1997).

As noted earlier, preparing trainees to succeed under novel conditions requires a qualitatively different approach than training for performance under routine conditions (Hesketh, 1997; Smith et al., 1997). While trainees need to have a firm understanding of the principles of the task domain (i.e., domain knowledge), they also need to develop skills to recognize changes in task demands, modify their task strategies, and evaluate the effectiveness of their new strategies (Ivancic & Hesketh, 2000). Specifically, researchers
have suggested that training for adaptive transfer requires an emphasis on self-regulation to both foster the regulatory skills necessary for adaptability as well as to increase trainees’ domain knowledge (Ivancic & Hesketh, 2000; Smith et al., 1997). Domain knowledge includes both basic knowledge (understanding fundamental information about a task) and strategic knowledge (understanding the deeper complexities of a task such as when to use certain strategies; Bell & Kozlowski, 2002). Domain knowledge is critical for adaptive transfer as successful performance in novel situations requires an understanding of the general facts and rules about a domain (i.e., basic knowledge) as well as an understanding of when and how to utilize different task strategies (i.e., strategic knowledge; Bell & Kozlowski, 2002; Kozlowski, 1998). This is consistent with research evidence showing basic and strategic knowledge to be important predictors of adaptive transfer (Bell & Kozlowski, 2008).

Training Interventions to Promote Adaptive Transfer

Researchers have examined a variety of training interventions designed to encourage different self-regulatory processes that theory suggests are important for promoting knowledge acquisition and adaptive transfer (e.g., Bell & Kozlowski, 2008). The current study focuses on two of these approaches: error management training (Keith & Frese, 2005, 2008) and prompting strategy regulation (Zaccaro, Conjar, Midberry, Ely, & Bryson, 2009; Zaccaro, Gulick et al., 2009; Zaccaro, Nelson, & Gulick, 2009). Each of these approaches and how they foster self-regulation, knowledge acquisition, and adaptive transfer are described in the following paragraphs.

Error Management Training
Error management training reflects an approach in which trainees are provided with minimal task guidance and are encouraged to actively explore the task domain in order to uncover the fundamental principles of the training task (Keith & Frese 2005, 2008). A hallmark of the error management training approach is that trainees are informed of the value of making errors and learning from their mistakes. Additionally, trainees are provided with error management strategies designed to mitigate the potential negative affect that might arise from making errors (Bell & Kozlowski, 2008; Dormann & Frese, 1994).

Past research suggests that error management training promotes trainees’ knowledge acquisition during training via two self-regulatory processes (Bell & Kozlowski, 2008; Keith & Frese, 2005). First, error management training encourages trainees to engage in metacognition (Keith & Frese, 2005). Metacognition includes cognitive regulatory activities related to the planning and monitoring of goal-directed behavior (Brown, Bransford, Ferrara, & Campione, 1983; Ford, Smith, Weissbein, Gully, & Salas, 1998). Trainees need to monitor their behavior in order to detect errors in their performance. After recognizing that an error has been made, the trainee then needs to understand the nature of the error and plan an alternate strategy (Ivancic & Hesketh, 2000). This process encourages trainees to reflect on why their strategy did not work, resulting in a better understanding of the fundamentals of the task including general facts and rules about the domain (i.e., basic knowledge). Second, error management training assists trainees in regulating their emotions (Keith & Frese, 2005). Kanfer, Ackerman, and Heggestad (1996) define emotion control as “the use of self-regulatory processes to
keep performance anxiety and other negative emotional reactions (e.g., worry) at bay during task engagement” (p. 186). Managing emotions during training is considered to be essential to knowledge acquisition, as negative thoughts and emotions can consume valuable attentional resources (Kanfer & Ackerman, 1989). Especially during complex tasks, failures in emotion control reduce trainees’ attentional capacity and inhibit short-term memory processes necessary for learning (Wood, George-Falvy, & Debowski, 1999). Trainees who experience negative emotions, such as dissatisfaction with their training performance, lose interest in training and become less willing to explore and experiment with the task (Bandura, 1997). Thus, error management training, with its emphasis on active learning and positive framing of errors, is thought to assist trainees in engaging in metacognition and emotion control, thereby increasing their basic knowledge levels (Bell & Kozlowski, 2008; Keith & Frese, 2005).

In addition to increasing basic knowledge via metacognition and emotion control, research suggests that error management training leads to higher levels of adaptive transfer (Keith & Frese, 2008) and that this effect is mediated through metacognition, emotion control, and basic knowledge (Bell & Kozlowski, 2008; Keith & Frese, 2005). First, metacognition encourages trainees to repeatedly engage in a cycle of reflecting on errors and generating alternate strategies. As such, metacognitive activity during training builds foundational knowledge and facilitates the development of flexible knowledge structures, which are a necessary precursor for the development of adaptive expertise (Frese & Zapf, 1994). Second, exercising emotion control during training is important for promoting adaptive transfer. Practicing maintaining emotion control in the face of errors
is important as it prepares trainees for performance in novel situations, such as not becoming anxious or frustrated when traditional performance strategies no longer apply (Keith & Frese, 2005). Taken together, this suggests that error management training is beneficial for promoting adaptive transfer through its influence on trainees’ metacognition, emotion control, and basic knowledge.

**Prompting Strategy Regulation**

Researchers have suggested that to foster adaptability, training programs should provide specific “cues to engage in adaptive thinking,” such as prompting trainees to engage in behaviors to promote strategy regulation (Ely, Zaccaro, & Conjar, 2009, p. 179). As a training intervention, prompting strategy regulation includes periodically presenting trainees with questions encouraging them to evaluate the effectiveness of their current strategies and to consider if there are other strategies that they could use (Sitzmann, Bell, Kraiger & Kanar, 2009; Zaccaro, Gulick et al. 2009; Zaccaro, Nelson et al., 2009).

Although prior research has demonstrated that prompting strategy regulation increases important training outcomes, particularly adaptive transfer (e.g., Zaccaro, Gulick et al., 2009), it has not elucidated the self-regulatory mechanisms by which this intervention exhibits its effects. The current study proposes that prompting strategy regulation promotes trainees’ knowledge acquisition via two self-regulatory processes. First, prompting strategy regulation should encourage trainees’ to engage in hypothesis testing. Hypothesis testing refers to the strategies trainees use when making predictions about the task and refining their task strategies for successful performance (Smith, 1996).
As trainees work to improve their performance, they do not try new performance strategies randomly. Rather their strategy refinement is based on their hypotheses about how the task works and is guided by their mental model of the domain (Bell, 2002; Grief & Keller, 1990). Trainees who engage in higher levels of hypothesis testing tend to explore more performance strategies and have higher levels of strategic knowledge (Bell, 2002).

Second, prompting strategy regulation should increase training motivation. Training motivation refers to the “direction, intensity, and persistence of learning-directed behavior in training contexts” (Colquitt, LePine, & Noe, 2000; p. 678). Trainees use goals as reference points for evaluating their training progress. When trainees are prompted to refine their strategies to increase their training performance they should increase the intensity of their learning-directed behaviors. Additionally, challenging trainees to refine their strategies and increase their performance provides motivation to engage in the discovery and development of task-strategies (Locke & Latham, 2002). This increased motivation toward identifying and trying new performance strategies leads trainees to understand deeper task elements, such as understanding when and why to apply certain strategies (i.e. strategic knowledge). This is consistent with research findings from Sitzmann et al. (2009) who found that trainees who received the strategy regulation prompts had higher levels of strategic knowledge than trainees who did not receive the prompts. Trainees with high strategic knowledge have complex and integrated frameworks of the training domain, which is a precursor of adaptability (Bell & Kozlowski, 2008; Horn, 2008; Kozlowski & Bell, 2006; Smith et al., 1997).
As described above, prompting strategy regulation is theorized to influence adaptive transfer via training motivation, hypothesis testing, and strategic knowledge. Specifically, prompting strategy regulation encourages trainees to remain motivated to improve their performance. Additionally, engaging in hypothesis testing during training is important for adaptive transfer as it provides the trainee with practice making hypotheses and predictions about the task, testing the predictions, and experimenting with performance strategies to develop those that are optimal for task performance (Smith, 1996). Engaging in these behaviors is critical for detecting the misalignment between current strategies and operating conditions which catalyzes adaptive behavior (Zaccaro, Banks, Kiechel-Koles, Kemp, & Bader, 2009). After noticing a misfit between their current strategy and environmental conditions, trainees need to approach the problem from a different perspective or frame of reference (Horn, 2008; Zaccaro, Banks et al., 2009). When trainees are prompted to engage in strategy regulation, they are encouraged to experiment with multiple strategies, thereby approaching the task from multiple perspectives. Individuals use frames of references to interpret their environment (Jacobs & Jaques, 1987) and engaging in frame changing—integrating different frames of reference and perspectives to arrive at a new strategy—has been identified as critical to adaptability (Horn, 2008; Zaccaro, Banks et al., 2009).

Training Interventions and Stages of Knowledge Acquisition

As described above, theory and empirical evidence suggests that these two training interventions promote learning and facilitate adaptive transfer via their effects on self-regulatory processes and knowledge. However in looking across adaptability training
research, most studies implement the same intervention across the entire training course (e.g., Bell & Kozlowski, 2008; Keith & Frese, 2005), despite evidence that some self-regulatory processes are differentially important in early and late knowledge acquisition (Kanfer & Ackerman, 1989, 1990). Specifically, Kanfer and Ackerman (1996) suggest that self-regulatory factors related to emotion control (e.g., reducing negative emotions after making errors) are important in early stages of knowledge acquisition, while processes related to motivation control (e.g., increasing effort devoted to the task) are important during later stages of knowledge acquisition. As such, the goal of this study was to examine if the effects of different sequences of these training interventions differ across stages of knowledge acquisition on self-regulation, knowledge, and adaptive transfer. The following paragraphs discuss the different stages of knowledge acquisition and propose which training intervention would be the most beneficial at each stage.

*Early Stage of Knowledge Acquisition*

The nature of knowledge acquisition is a complex and dynamic process. Most learning theories describe knowledge acquisition as being comprised of different stages of learning that begin with resource dependency and end in skilled performance (Anderson, 1982; Fitts & Posner, 1967; Schneider & Shiffrin, 1977). The early stage of learning is characterized by high cognitive demands as trainees work to understand task instructions, familiarize themselves with task goals, and formulate strategies for task accomplishment (Ackerman, 1992; Fitts & Posner, 1967; Weiss, 1990). According to Kanfer and Ackerman (1989), the early stage of knowledge acquisition requires
“substantial attentional resource demands” (p. 660) as trainees work to understand and perform the task.

In addition to the early stage of knowledge acquisition being the most cognitively demanding, it also has a large affective component. When trainees face a novel and unfamiliar environment, they are likely to experience increased anxiety. Early in training is also when the task appears the most daunting and trainees are likely to make the most mistakes (Kanfer & Ackerman, 1989, 1996; Weiss, 1990). Making mistakes in training can lead to frustration and negative affect (Frese & Altman, 1989). From a resource allocation perspective (Ellis & Ashbrook, 1988; Kanfer & Ackerman, 1989), negative affect such as anxiety and frustration are disruptive to learning as they divert attentional resources toward off-task thoughts, leaving fewer resources available to direct toward the task. This suggests that in the early stages of knowledge acquisition, trainees should benefit from error management training as it reinforces to trainees that they should not be discouraged if they make mistakes and that errors are a natural part of the learning process. Error management training increases trainees’ levels of emotion control (Keith & Frese, 2005), which is critical for managing the negative emotions that accompany error-prone performance.

During the early stage of knowledge acquisition, trainees should also benefit from engaging in metacognition including monitoring their behavior and detecting errors in their performance. Engaging in metacognition early in training not only facilitates trainees recognizing that they have made a mistake, but also assists trainees in diagnosing the nature of the error (Ivancic & Hesketh, 2000; Keith & Frese, 2005). Engaging in error
diagnosis encourages trainees to reflect on why they made a certain mistake, resulting in a better understanding of the fundamentals of the task including general facts and rules about the domain (i.e., basic knowledge). As such, trainees should benefit from error management training in the early stages of knowledge acquisition because it encourages active exploration of the task. Additionally, error management training should be beneficial early in training—when performance is error prone—as it increases trainees’ levels of metacognition, which assists trainees in diagnosing and learning from their errors (Keith & Frese, 2005).

Given the substantial attentional resource demands that are required during this early stage of knowledge acquisition (Kanfer & Ackerman, 1989), it is possible that prompting trainees at this stage to engage in strategy regulation—encouraging trainees to focus on more strategic aspects of the task—may create cognitive overload. Additionally, for complex tasks, learning should be sequenced to focus on the fundamentals before proceeding to the strategic aspects of the task (Bell & Kozlowski, 2002; Reigeluth, Merrill, Wilson, & Spiller, 1980). As prompting strategy regulation targets strategic knowledge—which is built on top of basic, foundational knowledge—encouraging trainees to focus on refining tasks strategies early in training, before they have learned the fundamentals of the task, may be counterproductive as it redirects trainees’ attention away from building basic knowledge.

In summary, it is hypothesized that early in training, receiving error management training leads to higher levels of adaptive transfer than being prompted to engage in strategy regulation and that this effect is mediated through higher levels of mid-training
emotion control, metacognition, and basic knowledge (see Figure 1). As described above, during the early stage of knowledge acquisition, trainees need to focus their cognitive resources toward building basic knowledge by understanding the foundational principles of the task while limiting the rise of negative affect resulting from making errors. This suggests that error management training would be beneficial early in training as it leads trainees to persist on new and difficult tasks and reduces the negative emotional effects of making errors during training (Heimbeck, Frese, Sonnentag, & Keith, 2003). Error management training also promotes trainees’ active exploration of the task—including making errors and learning from those errors—which increases trainees’ basic knowledge (Kozlowski et al., 2001).

Hypothesis 1: Trainees who receive error management training early in training will exhibit higher levels of mid-training a) emotion control, b) metacognition, c) basic knowledge, and d) adaptive transfer than trainees who receive strategy regulation prompts early in training.

Hypothesis 2: The relationship between error management training early in training and adaptive transfer will be mediated by mid-training a) emotion control, b) metacognition, and c) basic knowledge.

Late Stage of Knowledge Acquisition

As learning advances beyond initial knowledge acquisition, several changes in processing occur as a function of continued practice (Anderson, 1982). First, trainees begin to focus less on declarative knowledge and more on procedural knowledge. This leads to task automation (Schneider & Shiffrin, 1977) as trainees move through the
compilation and procedural phases of knowledge acquisition (Anderson & Fincham, 1994). Additionally, as trainees learn more about the task, performance becomes faster and less error prone—resulting in less of a need for emotion control to combat the frustration and negative affect that accompanies error making (Kanfer & Ackerman, 1996). Taken together, this suggests that the benefits of error management training for knowledge acquisition (increased metacognition and emotion control) decrease in later stages of knowledge acquisition because trainees have already learned the foundations of the task and are not making as many errors as they were early in training.

During the latter stages of training, trainees tend to cognitively withdraw due to fatigue and a belief that they have mastered the task (Bell & Kozlowski, 2002). If trainees perceive that their skill level is acceptable, instead of remaining motivated to refine their task strategies they may limit the intensity of their effort, thereby failing to achieve an optimal level of performance (Bell & Kozlowski, 2002; Kanfer & Ackerman, 1996). This is consistent with research evidence suggesting that trainees’ motivation tends to decrease across training (Kanfer & Ackerman, 1996). To combat this effect, late in training, trainees should benefit from interventions that increase training motivation so they continue to engage in learning-directed behaviors. This suggests that prompting strategy regulation should be incorporated late in training as that is when trainees need to be reminded to remain motivated, persist at refining their task strategies, and continue exploring new strategies to increase their performance.

As trainees gain task experience through repeated practice, their knowledge about the domain becomes meaningfully structured in memory (Kraiger, Ford, & Salas, 1993).
In the progression from novice to expert, trainees’ knowledge structures tend to become broader and deeper, with novices attending to surface features while experts attend to deeper structural features (Chi, Feltovich, & Glaser, 1981). Additionally, as noted by Gagné and Medsker (1996), during the later stages of knowledge acquisition, trainees become more adept at determining the appropriate situations for skill use. This suggests that prompting strategy regulation is beneficial late in training as trainees are better equipped to focus on building higher-order strategic knowledge after they have learned the fundamentals of the task (Ackerman, 1987; Anderson, 1982; Fitts & Posner, 1967). After trainees have learned the task fundamentals, they have the requisite knowledge to engage in hypothesis testing—thereby increasing their strategic knowledge.

In summary, it is hypothesized that later in training, being prompted to engage in strategy regulation leads to higher levels of adaptive transfer than receiving error management training and this effect is mediated through higher levels of post-training hypothesis testing, training motivation, and strategic knowledge. During the late stage of knowledge acquisition, trainees’ performance increases and they make fewer errors—leading trainees to become less motivated to continue to refine their performance strategies. This suggests that prompting strategy regulation should be beneficial late in training as it encourages trainees to examine the effectiveness of their performance strategies and look for alternate strategies that may improve their performance. The strategy regulation prompts should also encourage trainees to engage in hypothesis testing—including making task predictions and refining their task strategies—thereby increasing trainees’ strategic knowledge (Bell, 2002; Smith, 1996).
Hypothesis 3: Trainees who receive strategy regulation prompts late in training will exhibit higher levels of post-training a) training motivation, b) hypothesis testing, c) strategic knowledge, and d) adaptive transfer than trainees who receive error management training late in training.

Hypothesis 4: The relationship between strategy regulation prompts late in training and adaptive transfer will be mediated by post-training a) training motivation, b) hypothesis testing, and c) strategic knowledge.

Summary and Integration

The current study compares two training interventions that research has shown to facilitate adaptive transfer: error management training and prompting strategy regulation. Based on research on the nature of knowledge acquisition, this study examines the timing and sequencing of these interventions and the mediating mechanisms through which they influence adaptive transfer. As summarized in Figure 1, it is hypothesized that trainees receiving the error management training intervention early in training will have higher levels of adaptive transfer than trainees who receive the prompting strategy regulation manipulation early in training and that this effect will be mediated through higher levels of mid-training emotion control, metacognition, and basic knowledge. Conversely, it is hypothesized that trainees receiving the prompting strategy regulation manipulation late in training will have higher levels of adaptive transfer than trainees who receive the error management training intervention late in training and that this effect will be mediated through higher levels of post-training training motivation, hypothesis testing, and strategic knowledge.
METHOD

Participants

Participants included 148 undergraduates (64 men and 84 women) enrolled in psychology courses who completed the study in exchange for research participation credits. The average age of participants was 22 years. Almost half of the participants (47%) reported playing computer or video games at least once a week. There was no significant difference in the frequency of computer or video game playing across conditions, $\chi^2(3) = 1.04, p > .05$.

Task

The task used in this study was a computer-based radar-tracking simulation (TANDEM). TANDEM is a dynamic and complex task that has been used extensively to test training paradigms on undergraduate populations (e.g., Bell & Kozlowski, 2002, 2008; Gully, Payne, Koles, & Whiteman, 2002; Kozlowski & Bell, 2006). Participants engaged in eight practice trials consisting of 2.5 minutes reviewing a text-based manual, 4 minutes practicing in the simulation, and 1.5 minutes reviewing feedback on their practice performance. Throughout the eight practice trials, trainees needed to learn both basic and strategic knowledge about the task. In regards to basic knowledge, participants needed to learn how to select targets on their radar screen, collect information about the targets, and then use that information to make a series of four decisions about the target.
Trainees received points for each correct decision and lost points for each incorrect decision. The strategic knowledge required in TANDEM includes identifying two perimeters on their radar screen, monitoring targets approaching the perimeters, and prioritizing which targets to process. Trainees lost points when targets crossed their inner or outer perimeters.

Experimental Design and Procedures

Experimental sessions were conducted with groups of 2 to 10 participants. Each group was randomly assigned to an experimental condition. Upon arrival at the session, trainees were greeted and asked to provide their informed consent to participate in the study. After agreeing to participate, trainees completed the demographic and pre-training measures. Before beginning the practice trials, the experimenter provided the trainees with a brief (7 minute) demonstration of TANDEM that included an overview of the simulation features and decision rules. The demonstration also included an overview of the text-based manual that contained information on how to make decisions in the simulation. Trainees were then provided with 2.5 minutes to examine the text-based manual followed by a 1-minute introductory trial to provide them with an opportunity to become familiar with operating the simulation.

Following the familiarization trial, trainees began the eight practice trials. As noted earlier, each trial consisted of reviewing the text-based manual, practicing in the simulation, and receiving feedback on their performance. Trainees completed the manipulation check items as well as measures of self-regulation (metacognition, emotion control, hypothesis testing, and motivation) and knowledge (basic and strategic) both
mid-training (after practice trial four) and post-training (after practice trial eight). Finally, trainees participated in an additional trial designed to assess adaptive transfer. The entire study lasted approximately three hours.

Manipulations

**Error management training.** Consistent with past error management research (e.g., Bell & Kozlowski, 2008; Keith & Frese, 2005), trainees in the error management conditions received instructions to explore the simulation to develop an understanding of the task. Before each practice session, trainees received the following message, “An effective method for learning this simulation is to explore the task and develop your own understanding of it. While exploring the scenario, it is likely that you will make mistakes. When you make a mistake, remember that errors are a positive part of the learning experience. Try and learn from your mistakes to develop a better understanding of the simulation. The more errors you make, the more you learn.” Additionally, instructions framed errors as a positive part of the training process and encouraged trainees to use their mistakes to learn more about the task. Before each practice session, trainees also received the following instruction, “As you go through the next practice trial, remember that you are encouraged to make errors and learn from your mistakes to develop a better understanding of the simulation.”

**Prompting strategy regulation.** The strategy prompts were designed to focus trainees on developing strategic knowledge relevant to TANDEM. Past research using TANDEM has identified two critical areas of strategic knowledge: situational assessment and target prioritization (Kozlowski, Toney, Mullins, Bell, & Weissbein, 1998).
Situational assessment requires trainees to understand how to use the zoom function, how to identify defensive perimeters, and how to locate and utilize marker targets, while target prioritization requires trainees to make decisions about which targets constitute the greatest threats. One set of questions was designed to focus on trainees’ situational assessment (How you are monitoring your perimeters? Is there another strategy you could try that would improve your performance?) and the other set of questions was designed to focus on trainees’ target prioritization (How are you choosing which targets to examine first? Is there another strategy you could try that would improve your performance?). This type of prompting is consistent with interventions used by Zaccaro and colleagues to encourage trainees to engage in frame switching and examine different perspectives for approaching the task (Zaccaro, Conjar et al., 2009; Zaccaro, Gulick et al., 2009; Zaccaro, Nelson et al., 2009). The strategy prompts were administered immediately before each study session. Only one set of questions was administered during each trial (situational assessment prompts during odd trials and target prioritization prompts during even trials).

*Timing of intervention.* All participants received one training manipulation (error management training or prompting strategy regulation) early in training (trials 1 through 4) and one training manipulation (error management training or prompting strategy regulation) late in training (trials 5 through 8). Early training was defined as trials 1 through 4 based on previous research using TANDEM that has shown this is when trainees acquire basic knowledge and make the greatest number of errors (Bell & Kozlowski, 2002). This created four possible intervention conditions: 1) error
management early and late; 2) strategy prompts early and late; 3) error management early, strategy prompts late; 4) strategy prompts early, error management late.

**Measures**

*Cognitive ability.* Given the strong relationship between cognitive ability and both knowledge acquisition (Colquitt, LePine, & Noe, 2000; Ree & Earles, 1991) and adaptive transfer (Bell & Kozlowski, 2008), cognitive ability was assessed to use as a covariate in analyses predicting basic knowledge, strategic knowledge, and adaptive transfer. Prior to the training session, all participants were administered the Wonderlic Personnel Test. The Wonderlic Personnel Test is a well-known and widely used index of general cognitive ability (Chan, 1997).

*Goal orientation.* Trainees’ goal orientations have also been shown to predict self-regulatory processes (Bell & Kozlowski, 2008; Payne, Youngcourt, & Beaubien, 2007). As such, goal orientation dimensions were assessed to use as covariates in analyses predicting self-regulatory processes. Goal orientation dimensions were assessed pretraining using a 13-item measure adapted from VandeWalle (1997). The measure includes scales for mastery, performance-prove, and performance-avoid goal orientation. Sample items include, “I often look for opportunities to develop new skills and knowledge” (mastery); “I prefer projects where I can prove my ability to others” (performance-prove); and “Avoiding a show of low ability is more important to me than learning a new skill” (performance-avoid). The three scales showed adequate reliabilities (mastery, α = .85; performance-prove, α = .79; performance-avoid α = .86).
Metacognition. Trainees’ metacognitive activity was assessed with a 15-item scale from Schmidt and Ford (2003). The items were designed to assess the degree to which trainees engaged in monitoring and planning behaviors. A sample item includes, “During this training program, I noticed where I made mistakes and focused on improving those areas.” Reliabilities for this scale were .93 (mid-training) and .95 (post-training).

Emotion control. Emotion control was assessed using a 5-item measure from Warr and Downing (2000). This scale assesses trainees’ affective regulation in response to difficulties in training. A sample item includes, “I told myself not to worry when things were difficult.” Reliabilities for this scale were .88 (mid-training) and .95 (post-training).

Hypothesis testing. Hypothesis testing was assessed using a 6-item measure from Bell (2002). The hypothesis-testing scale assesses the extent to which trainees made and tested predictions about the task and experimented with different task strategies. A sample item includes, “I experimented with different task strategies to handle the challenges I faced in the scenarios.” Reliabilities for this scale were .87 (mid-training) and .90 (post-training).

Training motivation. Training motivation was assessed using a 6-item measure adapted from Noe and Schmitt (1986). The measure assesses the degree to which trainees’ were motivated and exerted effort during training. A sample item includes, “During training, I was motivated to learn the simulation.” Reliabilities for this scale were .95 (mid-training) and .93 (post-training).
Basic knowledge. Mid- and post-training, participants completed an 11-item multiple-choice test that assesses the degree to which they acquired declarative and procedural knowledge about the task (e.g., basic operating features of the task). Basic knowledge scores were computed as percentage of questions answered correctly.

Strategic knowledge. Mid- and post-training, participants also completed an 11-item multiple-choice test that assesses the degree to which participants’ acquired strategic knowledge about the task, including the trainees’ ability to understand the deeper elements of the situation: situational assessment and target prioritization (Bell, 2002). Situational assessment requires trainees to understand how to use the zoom function, identify defensive perimeters, and locate and utilize marker targets. Target prioritization requires trainees’ to make decisions about which targets pose the greatest threat (all scenarios include multiple targets of varying degrees of threat). Strategic knowledge scores were computed as percentage of questions answered correctly.

Adaptive transfer. After completing the knowledge tests, trainees participated in an adaptive transfer trial. In this trial, trainees did not receive any of the manipulations and received instructions to do their best on the trial. Consistent with past research using TANDEM (Bell & Kozlowski, 2002, 2008), the adaptive transfer trial was longer and more challenging (i.e., more targets) than the training trials. Additionally, for the adaptive transfer trial the “rules of engagement” changed such that the point deduction for letting targets cross the perimeter increased and targets appear more suddenly and closer to the perimeters than in the training trials. Based on these changes, success in the adaptive
transfer trial required trainees to alter their performance strategy and calculate strategic trade-offs in deciding which perimeters to defend.

**Analytic Strategy**

The first set of analyses examined the effects of the training manipulations and the timing of the manipulations on trainees’ self-regulatory processes, knowledge, and adaptive transfer. Analyses of covariance variance, including goal orientations as covariates, were used to examine the effects of training condition on self-regulatory processes. Analyses of covariance, including cognitive ability as a covariate, were used to examine the effects of training condition on knowledge and adaptive transfer. For all directional hypotheses, one-tailed tests of significance were used.

The second set of analyses used structural equation modeling to examine the mediation hypotheses as well as the overall fit of the proposed model. Researchers have debated the utility of different fit indices and have advocated the presentation of multiple indices of model fit (Bludau, Herman, Cortina, & Williams, 2007; Schumacker & Lomax, 2004). Model fit was assessed by examining the comparative fit index (CFI), incremental fit index (IFI), nonnormed fit index (NNFI) and root mean square error of approximation (RMSEA). Following convention, CFI, IFI, and NNFI values above 0.90 are interpreted as indicating acceptable fit and values above 0.95 indicate good fit (Hu & Bentler, 1999). In interpreting the RMSEA, values between 0.05 and 0.08 are interpreted as indicating reasonable fit and values below 0.05 indicate close approximate fit (Kline, 2004).
RESULTS

The means, standard deviations, and intercorrelations for all variables examined in the study are presented in Table 1. Appendix A contains the means and standard deviations of mid- and post-training measures by training condition (early and late). As several of the correlations among the self-regulatory processes in the proposed model were strong, a confirmatory factor analysis (CFA) was conducted to examine the factor structure of the self-regulatory processes. The CFA revealed that a four-factor model of metacognition, emotion control, hypothesis testing, and training motivation provided acceptable fit to the data, $\chi^2(458, N = 148) = 1050.76, p < .05$, CFI = 0.95, IFI = 0.95, NNFI = 0.94, RMSEA = 0.09. Additionally, the fit statistics for the one-factor model—in which all the indicators loaded on one self-regulation factor—did not fit the data well, $\chi^2(464, N = 148) = 2597.95, p < .05$, CFI = 0.81, IFI = 0.81, NNFI = 0.80, RMSEA = 0.23. Together this suggests that the four self-regulatory processes measured capture distinct, but related factors.

Manipulation Checks

Mid-training and post-training, participants responded to four items designed to examine if the training intervention manipulations created the desired states in the trainees. To test if trainees in the error management training condition felt encouraged to make errors and interpreted their errors as learning opportunities, all trainees responded
to two items “I felt encouraged to make errors during the trials” and “I felt discouraged when I made mistakes.” In the first half of training, participants in the error management training condition reported feeling more encouraged to make errors ($F(1, 145) = 10.13, p < .05$) and less discouraged when they made mistakes ($F(1, 145) = 4.12, p < .05$) than trainees who received the prompting strategy regulation manipulation. Similarly, in the second half of training, participants in the error management training condition reported feeling more encouraged to make errors ($F(1, 145) = 12.51, p < .05$) and less discouraged when they made mistakes ($F(1, 145) = 6.65, p < .05$) than trainees who received the prompting strategy regulation manipulation.

To examine if trainees in the prompting strategy regulation condition were actively trying to refine their performance strategies, all trainees responded to two items “I tried different strategies for monitoring the perimeters” and “I tried different strategies for prioritizing targets.” In the first half of training, participants receiving the prompting strategy regulation manipulation reported higher levels of agreement that they tried different strategies for monitoring the perimeters ($F(1, 145) = 7.20, p < .05$) and for prioritizing targets ($F(1, 145) = 4.43, p < .05$) than trainees in the error management training condition. Similarly, in the second half of training, participants receiving the prompting strategy regulation manipulation reported higher levels of agreement that they tried different strategies for monitoring the perimeters ($F(1, 145) = 4.94, p < .05$) and for prioritizing targets ($F(1, 145) = 4.55, p < .05$) than trainees receiving the error management training manipulation.

**Self-Regulatory Processes and Knowledge Levels**
Hypothesis 1 predicted that trainees who received error management training early in training would have higher levels of mid-training a) emotion control, b) metacognition, and c) basic knowledge than trainees who received the strategy regulation prompts. Training condition in the first half of training significantly predicted trainees’ mid-training emotion control, $F(1, 142) = 6.42, p < .05$. As shown in Table 2, trainees who received the error management manipulation in the first half of training reported significantly higher levels of mid-training emotion control than trainees who received the strategy regulation prompts manipulation ($M = 3.94$ and $3.60$, respectively), providing support for Hypothesis 1a. Training condition in the first half of training did not significantly predict trainees’ mid-training metacognition, $F(1, 142) = 0.40, p > .05$. Thus, Hypothesis 1b was not supported.

In support of Hypothesis 1c, training condition in the first half of training predicted trainees’ mid-training basic knowledge levels, $F(1, 144) = 2.87, p < .05$. Trainees who received the error management manipulation in the first half of training had higher mid-training basic knowledge levels than trainees who received the strategy regulation manipulation ($M = 0.79$ and $0.73$, respectively).

Hypothesis 3 predicted that trainees who received the strategy regulation prompts late in training would have higher post-training levels of a) training motivation, b) hypothesis testing, and c) strategic knowledge than trainees who received error management training. Training condition in the second half of training significantly predicted trainees’ post-training motivation, $F(1, 142) = 8.99, p < .05$. As shown in Table 3, trainees who received the strategy regulation manipulation in the second half of
training reported higher levels of post-training motivation than trainees who received the 
error management manipulation ($M = 4.32$ and $3.82$, respectively), providing support for 
Hypothesis 3a. However, training condition in the second half of training did not 
significantly predict trainees’ post-training hypothesis testing, $F (1, 142) = 1.22, p > .05$.
Thus, Hypothesis 3b was not supported.

In support of Hypothesis 3c, training condition in the second half of training 
predicted trainees’ post-training strategic knowledge levels, $F (1, 143) = 18.18, p < .05$.
Trainees who received the strategy regulation manipulation in the second half of training 
had higher post-training strategic knowledge levels than trainees who received the error 
management manipulation ($M = 0.65$ and $0.51$, respectively).

**Adaptive Transfer**

Hypotheses 1d and 3d examined the effects of training condition on adaptive 
transfer. The means and standard deviations for each condition are presented in Table 4. 
In support of Hypothesis 1d, trainees who received the error management manipulation in 
the first half of training had higher levels of adaptive transfer than trainees who received 
the strategy regulation manipulation in the first half of training, $F (1, 143) = 5.73, p < .05$.
Similarly, in support of Hypothesis 3d, trainees who received the strategy regulation 
manipulation in the second half of training had higher levels of adaptive transfer than 
trainees who received the error management manipulation in the second half of training, 
$F (1, 143) = 4.08, p < .05$. Follow-up paired comparisons revealed that trainees who 
received error management training early in training and the strategy regulation prompts late in training had higher levels of adaptive transfer than trainees who received error
management training both early and late in training ($F_{1, 71} = 3.12, p < .05$), trainees who received strategy regulation prompts both early and late in training ($F_{1, 72} = 4.09, p < .05$), and trainees who received strategy regulation prompts early in training and error management training late in training ($F_{1, 73} = 10.60, p < .05$). None of the other paired comparisons were significant.

Model Testing

The overall model and mediating paths was tested using structural equation modeling in LISREL. Fit statistics for the structural equation models are presented in Table 5. The first model tested was the hypothesized model presented in Figure 1. The fit statistics suggested that the hypothesized model did not provide a good fit to the data, \( \chi^2(27, N = 148) = 210.97, p < .05, CFI = 0.67, IFI = 0.68, NNFI = 0.46, RMSEA = 0.22 \). Additionally, the model included several non-significant paths: early training condition did not significantly predict metacognition ($\beta = 0.07, p > .05$) or basic knowledge ($\beta = -0.04, p > .05$); late training condition did not significantly predict hypothesis testing ($\beta = -0.04, p > .05$); and hypothesis testing did not significantly predict strategic knowledge ($\beta = -0.05, p > .05$).

Based on the inadequate fit of the hypothesized model, alternative models were tested. Consistent with the recommendation from Schumaker and Lomax (2004), hypothesized parameters that were not significantly different from zero were eliminated. Dropping these parameters removed metacognition and hypothesis testing from the model. The fit statistics for this model (alternate model 1), suggested a better fit to the data than the hypothesized model, although not all of the indices indicated acceptable fit,
Next, the modification indices from the revised model were used to identify potential model respecifications. To avoid capitalizing on sampling error, only modifications that were theoretically grounded were examined (Schumaker & Lomax, 2004). First, a path was included from emotion control to training motivation. This is consistent with self-regulation theories that describe self-regulation as a dynamic and cyclical process in which self-regulatory processes are interrelated (Butler & Winne, 1995; Kanfer & Ackerman, 1989; Pintrich, 2000). Specifically, Beier and Kanfer (2009) suggested that emotion control influences subsequent training motivation as failures in emotion control lead to increased frustration, which may affect trainees’ valence, instrumentality, and expectancy for training. Second, a path was included from basic knowledge to strategic knowledge. Modeling this path is consistent with Anderson’s (1982, 1983) theory of learning which suggests that foundational knowledge such as the declarative and procedural components of basic knowledge are necessary for the development of higher level knowledge (i.e., strategic knowledge). An examination of the fits statistics for this revised model (alternate model 2), suggested that including these two paths significantly improved model fit ($\chi^2$ difference = 33.50, $df = 2$, $p < .05$) and the fit statistics all indicated good model fit (CFI = 0.98, IFI = 0.98, NNFI = 0.96, RMSEA = .06). Standardized parameter estimates of the final model are presented in Figure 2.

The joint significance test (MacKinnon, Lockwood, Hoffman, West, & Sheets, 2002) was used to test the mediated effects of early and late training condition on

$\chi^2(15, N = 148) = 54.02, p < .05$, CFI = 0.91, IFI = 0.91, NNFI = 0.82, RMSEA = 0.13.
adaptive transfer. Simulation results have suggested that the joint significance test is the preferred method for hypothesis testing in multiple mediation models in terms of successfully controlling Type I error while maintaining good power (Mathieu, DeShon, & Bergh, 2008; Taylor, MacKinnon, & Tein, 2008). In the case of a three-path mediation model, the joint significance test finds evidence of mediation when each of the three paths (IV to M₁, M₁ to M₂, and M₂ to DV) are significantly different than zero (Taylor et al., 2008). As shown in Figure 2, all three paths linking early training condition to adaptive transfer via emotion control and basic knowledge were significant—providing support for Hypotheses 2a and 2c. Similarly, the model provides support for Hypotheses 4a and 4c, as all three paths linking late training condition to adaptive transfer via motivation and strategic knowledge were significant. However, Hypotheses 2b and 4b were not supported as metacognition and hypothesis testing were dropped from the model.

To examine the nature of the mediation (full or partial), the Baron and Kenny (1986) framework was extended to the multiple mediation model as described by Taylor and colleagues (2008). Specifically, the direct effect from the independent variable to the dependent variable was added to examine if a significant relationship remained after accounting for the mediators (alternate model 3). The direct path from early training condition to adaptive transfer and from the late training condition to adaptive transfer were both not significant, (β = -0.11, p > .05; β = 0.02, p > .05, respectively). Additionally, including these two paths did not significantly improve model fit over the
fully mediated model ($\chi^2$ difference = 3.88, $df = 2, p > .05$), providing support for full mediation.

**Post Hoc Analyses**

To further examine the effects of the training interventions on self-regulatory processes across the stages of knowledge acquisition, post hoc ANCOVAs (controlling for goal orientations) were conducted to examine the influence of early training condition on the self-regulatory processes that theory suggests are important later in training (hypothesis testing and motivation) and the influence of late training condition on the self-regulatory processes that theory suggests are important early in training (metacognition and emotion control). Prompting strategy regulation in the first half of training did not significantly predict levels of mid-training motivation ($F (1, 142) = 0.24, p > .05$) or hypothesis testing, $F (1, 142) = 1.01, p > .05$. Similarly, receiving error management training late in training did not significantly predict post-training emotion control ($F (1, 142) = 0.96, p > .05$) or metacognition, $F (1, 142) = 0.00, p > .05$. Taken together with the supported model, these findings highlight the importance of considering the timing of implementing self-regulatory interventions. Specifically, receiving error management training increased emotion control early in training and receiving the strategy regulation prompts increased training motivation late in training.
DISCUSSION

As organizations’ need for an adaptive workforce has continued to grow, training research has examined a variety of training interventions designed to foster adaptive transfer. Training for adaptability requires strategies and designs that differ from those typical in traditional instructional systems (Kozlowski, 1998; Kozlowski et al., 2001; Smith et al., 1997). Successful training interventions have focused on encouraging self-regulation in order to increase knowledge and ultimately, adaptive transfer (e.g., Bell & Kozlowski, 2008; Keith & Frese, 2005). Despite the research progress made in this area, the research has emerged separately from the literature on the nature of knowledge acquisition. The goal of the current study was to integrate research on adaptability training with the cognitive psychology literature on the nature of knowledge acquisition to better understand how training interventions may be sequenced to promote self-regulation, knowledge, and adaptive transfer. The paragraphs below highlight the key findings of this research and discuss the implications for future research.

Implications for Theory and Practice

The findings from this study provide preliminary support for the sequencing of training interventions across different stages of knowledge acquisition. Past research has shown the effectiveness of error management training and prompting strategy regulation on adaptive transfer (Keith & Frese, 2005, 2008; Zaccaro, Conjar et al., 2009; Zaccaro,
Gulick et al., 2009). The current research extends those findings by examining the relative effectiveness of each of these interventions early and late in training. When predicting adaptive transfer, the results indicate that early in training, error management training was more beneficial than prompting strategy regulation, while later in training, prompting strategy regulation was more beneficial than error management training. It is important to note that high levels of adaptive transfer were not simply a function of receiving both interventions—trainees who received the strategy regulation prompts early in training and error management training late in training had the lowest levels of adaptive transfer. Rather, receiving each intervention at the theoretically optimal time during knowledge acquisition (i.e., error management training early in training and prompting strategy regulation late in training) led to the highest levels of adaptive transfer.

The results from the current study also lend support to Kanfer and Ackerman’s (1996) proposition that self-regulatory factors related to emotion control are important in early stages of knowledge acquisition while processes related to motivation control are important during the later stages of knowledge acquisition. Specifically, early in training, when trainees’ performance is error prone, error management training increased trainees’ basic knowledge via emotion control. This is consistent with research by Ivancic and Hesketh (1995/1996) indicating that error management training decreases the likelihood that trainees will become frustrated when they make errors—thereby mitigating the negative consequences generally associated with making errors. Receiving the error management training intervention early in training encouraged trainees to minimize the
anxiety and frustration from making mistakes, thereby freeing up attentional resources to explore the task in order to learn basic task knowledge.

However, later in training—when trainees’ performance has become more refined and trainees may be less motivated to continue to increase their knowledge—prompting strategy regulation was the more beneficial intervention for increasing strategic knowledge. Specifically, the strategy regulation prompts were designed to motivate trainees by fostering active exploration of key performance strategies from alternate perspectives. Motivating trainees to continue to look for ways to refine their performance strategies leads trainees to try more performance strategies. As they experiment with different strategies, trainees gain an understanding the deeper complexities of a task such as when to use certain strategies, thereby increasing their strategic knowledge.

These findings are also consistent with cognitive psychology research suggesting that training programs should focus on building basic knowledge early in training before focusing on strategic knowledge (Anderson, 1983; Bell & Kozlowski, 2002). Early in training, error management training—with its focus on exploring fundamental task features—was more beneficial for building basic knowledge than prompting strategy regulation. However, later in training, after trainees have built foundational knowledge, encouraging them to reflect on their performance strategies and consider if alternate strategies would improve their performance, was more beneficial to building strategic knowledge. Given the importance of both basic and strategic knowledge to adaptive transfer (Bell & Kozlowski, 2008), these results highlight the importance of designing
training programs that include interventions that focus on building basic knowledge early in training and strategic knowledge later in training.

Contrary to the hypotheses, training condition did not influence metacognition and hypothesis testing. As each of these interventions are rooted in active learning principles, and encourage active exploration (Bell & Kozlowski, 2008; Zaccaro, Conjar et al., 2009) it is possible that both interventions encouraged trainees to plan and monitor their goal-directed behavior while also making predictions about how the task works and refining their task strategies to improve their performance—leading both groups to have similar levels of metacognition and hypothesis testing. As future studies examine additional training interventions that promote adaptive transfer, research is needed to better understand the self-regulatory processes that mediate these interventions, so that they can be optimally sequenced into training curriculums.

The support for the mediation hypotheses highlights the importance of self-regulatory processes and knowledge to adaptive transfer. Numerous researchers have argued for the centrality of self-regulation and knowledge for increasing adaptive transfer (Bell & Kozlowski, 2008; Keith & Frese, 2005; Kozlowski, 1998; Smith et al. 1997). The current findings provide evidence for this argument and highlight how the mediation processes can be incorporated into a temporal framework that accounts for the nature of knowledge acquisition. These findings suggest that theories on training for adaptive transfer should not only incorporate interventions that target self-regulation and knowledge as key mediators, but also consider the timing of implementing these
interventions based on the relative importance of the mediators across the stages of knowledge acquisition.

Limitations and Directions for Future Research

There are several limitations of this research that should be noted. The first limitation is the potential generalizability of the results. The current findings are based on data collected from undergraduates conducting an artificial task with a limited time horizon—potentially limiting the degree to which the results can be directly generalized to other training settings. However, the design of the study includes realistic training material that was designed to mirror a real training paradigm. Additionally, the training task is consistent with previous adaptability training research (e.g., Bell & Kozlowski, 2002, 2008) allowing for the current study to build upon this past body of research.

A second limitation is the nature of the measure of adaptive transfer. Researchers have differentiated three levels of adaptive transfer (Smith et al., 1997). The first level, reflecting minimal adaptability, occurs when successful performance on the transfer task requires the application of the same performance strategies learned in training. The second level refers to transfer tasks that require trainees to adjust the performance strategies learned in training in order to succeed. The third level, reflecting the highest adaptability requirement, occurs when successful performance on the transfer task involves the creation of entirely new performance strategies—different from those learned in training. Using these definitions, the adaptive transfer task in the current study reflects level two adaptive transfer—requiring trainees to adjust their performance strategies, but not to create entirely new performance strategies. As such, these research
findings are limited in their generalizability to other level-two outcomes. The adaptability literature would benefit from additional research examining whether the same effects of sequencing these training interventions are replicated using level-three outcomes.

For the purpose of the current study, training was divided into early and late training based on previous TANDEM research suggesting that trainees make the majority of their errors in the first four trials with performance leveling off during trials five through eight. Although this differentiation was useful to test the current training paradigm, it is likely that the lengths of the stages of knowledge acquisition are not temporally uniform across trainees. For example, some trainees may have been making relatively fewer errors by trial three, while others may have needed until trials five or six to reach the same level of performance. This suggests that future research on sequencing training designs should examine adaptive training systems that can dynamically track trainees’ learning progress in order to deliver training interventions that are appropriate for a trainee’s specific learning curve.

The current study only focused on two training interventions that research has identified as increasing adaptive transfer. However, research has also found other interventions to be effective in promoting adaptive transfer—including practice variety (Zaccaro, Gulick et al., 2009; Zaccaro, Nelson et al., 2009) and adaptive guidance (Bell & Kozlowski, 2002). Future research is needed to examine ways in which these training interventions can be optimally combined and sequenced in training based on the nature of knowledge acquisition. For example, incorporating practice variety in training provides individuals with the opportunity to practice diagnosing environmental changes. However,
this intervention may prove the most beneficial when incorporated later in training—after trainees have established the foundational knowledge base required to diagnose environmental changes (Ely et al., 2009).

Conclusion

Recent research has provided insight into training interventions that increase adaptive transfer (e.g., Bell & Kozlowski, 2002, 2008; Keith & Frese, 2005; Zaccaro, Gulick et al., 2009; Zaccaro, Nelson et al., 2009). Although this research base has provided promising results, it evolved separately from research on the nature of knowledge acquisition. This study integrates these two research fields by examining the effect of sequencing two training interventions—error management training and prompting strategy regulation—across different stages of knowledge acquisition. When training for adaptive transfer, the results highlight the importance of incorporating error management training early in training to promote emotion control and build basic knowledge; while late in training, prompting strategy regulation is more beneficial to increase training motivation and facilitate strategic knowledge. As such, the approach tested here, in which training interventions were sequenced in a curriculum based on the nature of knowledge acquisition, reflects a promising direction for further exploration and innovation in training for adaptive transfer.
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</tr>
<tr>
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<td>.03</td>
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<td>.24</td>
<td>-.05</td>
<td>–</td>
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</tr>
<tr>
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<td>0.80</td>
<td>-.21</td>
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<td>.04</td>
<td>-.05</td>
<td>.31</td>
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<tr>
<td>9. Hypothesis testing (mid-training)</td>
<td>3.51</td>
<td>0.77</td>
<td>.11</td>
<td>-.03</td>
<td>.03</td>
<td>.31</td>
<td>.18</td>
<td>-.09</td>
<td>.67</td>
<td>.25</td>
<td>–</td>
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<tr>
<td>10. Training motivation (mid-training)</td>
<td>4.13</td>
<td>0.81</td>
<td>.06</td>
<td>.09</td>
<td>.04</td>
<td>.14</td>
<td>.10</td>
<td>.08</td>
<td>.57</td>
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<tr>
<td>11. Basic knowledge (mid-training)</td>
<td>0.76</td>
<td>0.21</td>
<td>-.14</td>
<td>.14</td>
<td>.45</td>
<td>-.07</td>
<td>-.15</td>
<td>.00</td>
<td>-.03</td>
<td>.39</td>
<td>.47</td>
</tr>
<tr>
<td>12. Strategic knowledge (mid-training)</td>
<td>0.46</td>
<td>0.23</td>
<td>.02</td>
<td>.17</td>
<td>.39</td>
<td>.20</td>
<td>.08</td>
<td>-.04</td>
<td>.17</td>
<td>.21</td>
<td>.25</td>
</tr>
<tr>
<td>13. Metacognition (post-training)</td>
<td>3.74</td>
<td>0.68</td>
<td>-.07</td>
<td>.06</td>
<td>.05</td>
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<td>.18</td>
<td>-.03</td>
<td>.57</td>
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<td>14. Emotion control (post-training)</td>
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<td>-.17</td>
<td>-.06</td>
<td>-.06</td>
<td>.13</td>
<td>.03</td>
<td>.05</td>
<td>.23</td>
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<td>.21</td>
<td>.05</td>
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<td>.16</td>
<td>.09</td>
<td>.41</td>
<td>.28</td>
<td>.33</td>
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<td>17. Basic knowledge (post-training)</td>
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<td>-.15</td>
<td>.13</td>
<td>.43</td>
<td>.12</td>
<td>-.03</td>
<td>-.02</td>
<td>.10</td>
<td>.42</td>
<td>.08</td>
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<tr>
<td>18. Strategic knowledge (post-training)</td>
<td>0.58</td>
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<td>-.05</td>
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<td>.45</td>
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<td>-.00</td>
<td>-.10</td>
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<td>.09</td>
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</table>

Note. For training condition, error management training = 0 and prompting strategy regulation = 1. N = 148. *p < .05, one-tailed.
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<tr>
<td>11. Basic knowledge (mid-training)</td>
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</tr>
<tr>
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<td>14. Emotion control (post-training)</td>
<td>.22*</td>
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<td>.10</td>
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<tr>
<td>15. Hypothesis testing (post-training)</td>
<td>.43*</td>
<td>.00</td>
<td>.18*</td>
<td>.69*</td>
<td>.27*</td>
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<td>16. Training motivation (post-training)</td>
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<td>.53*</td>
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<td>.14*</td>
<td>.23*</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>18. Strategic knowledge (post-training)</td>
<td>.23*</td>
<td>.46*</td>
<td>.62*</td>
<td>.15*</td>
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<td>.19*</td>
<td>.26*</td>
<td>.69*</td>
<td>.57*</td>
<td></td>
</tr>
</tbody>
</table>

*Note.* For training condition, error management training = 0 and prompting strategy regulation = 1.

\(N = 148.\)

\({p < .05, \text{ one-tailed.}}\)
<table>
<thead>
<tr>
<th>Early Training Condition</th>
<th>Emotion Control</th>
<th>Metacognition</th>
<th>Basic Knowledge</th>
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<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
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<tr>
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<td>3.65</td>
</tr>
<tr>
<td>Strategy Regulation Prompts</td>
<td>3.60</td>
<td>0.76</td>
<td>3.75</td>
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*Note. N = 148.*
Table 3

Means and Standard Deviations of Post-Training Training Motivation, Hypothesis Testing, and Strategic Knowledge by Late Training Condition

<table>
<thead>
<tr>
<th>Late Training Condition</th>
<th>Training Motivation</th>
<th>Hypothesis Testing</th>
<th>Strategic Knowledge</th>
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<td></td>
<td>( M )</td>
<td>( SD )</td>
<td>( M )</td>
</tr>
<tr>
<td>Error Management Training</td>
<td>3.82</td>
<td>0.96</td>
<td>3.59</td>
</tr>
<tr>
<td>Strategy Regulation Prompts</td>
<td>4.32</td>
<td>0.77</td>
<td>3.53</td>
</tr>
</tbody>
</table>

*Note. \( N = 148 \).*
Table 4

*Means and Standard Deviations of Adaptive Transfer by Training Condition*

<table>
<thead>
<tr>
<th>Early Training Condition</th>
<th>Late Training Condition</th>
<th>Adaptive Transfer</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
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<tr>
<td>Error Management Training</td>
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<td></td>
</tr>
<tr>
<td>Error Management Training</td>
<td>Strategy Regulation Prompts</td>
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</tr>
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<td>Strategy Regulation Prompts</td>
<td>Error Management Training</td>
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<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Strategy Regulation Prompts</td>
<td>Strategy Regulation Prompts</td>
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</table>

*Note. N = 148.*
Table 5

*Goodness-of-Fit Summary for Structural Equation Models*

<table>
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<th>Model</th>
<th>df</th>
<th>$\chi^2$</th>
<th>$\chi^2$/df</th>
<th>CFI</th>
<th>IFI</th>
<th>NNFI</th>
<th>RMSEA</th>
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</thead>
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<td>0.68</td>
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<td>0.91</td>
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<td>0.98</td>
<td>0.96</td>
<td>0.06</td>
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<td>0.99</td>
<td>0.97</td>
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</tbody>
</table>

*Note.* CFI = comparative fit index; IFI = incremental fit index; NNFI = nonnormed fit index; RMSEA = root-mean-square error of approximation.
Figure 1.

Hypothesized model of the effects of early and late training condition on self-regulatory processes, knowledge, and adaptive transfer.
Figure 2.

Structural equation model results for alternative model with full mediation. Standardized path coefficients are reported. Dashed lines represent exploratory paths. Training condition is coded such that Error Management Training is coded as 1 and Strategy Regulation Prompts is coded as 2. Although not depicted in the model, cognitive ability was included as a covariate predicting basic knowledge, strategic knowledge, and adaptive transfer.

*p < .05.
APPENDIX A: Supplemental Descriptive Statistics

*Means and Standard Deviations of Mid-Training Measures by Early Training Condition*

<table>
<thead>
<tr>
<th>Early Training Condition</th>
<th>Emotion Control</th>
<th>Metacognition</th>
<th>Training Motivation</th>
<th>Hypothesis Testing</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Error Management Training</td>
<td>3.94</td>
<td>0.81</td>
<td>3.65</td>
<td>0.81</td>
</tr>
<tr>
<td>Strategy Regulation Prompts</td>
<td>3.60</td>
<td>0.76</td>
<td>3.75</td>
<td>0.63</td>
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</table>

N = 148.

<table>
<thead>
<tr>
<th>Early Training Condition</th>
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<th>Strategic Knowledge</th>
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</thead>
<tbody>
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<td>SD</td>
</tr>
<tr>
<td>Error Management Training</td>
<td>0.79</td>
<td>0.19</td>
</tr>
<tr>
<td>Strategy Regulation Prompts</td>
<td>0.73</td>
<td>0.23</td>
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</table>
### Means and Standard Deviations of Post-Training Measures by Late Training Condition

<table>
<thead>
<tr>
<th>Late Training Condition</th>
<th>Emotion Control</th>
<th>Metacognition</th>
<th>Training Motivation</th>
<th>Hypothesis Testing</th>
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<td>M</td>
<td>SD</td>
</tr>
<tr>
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<td>0.84</td>
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<td>Strategy Regulation Prompts</td>
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<td>1.03</td>
<td>3.75</td>
<td>0.74</td>
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*N = 148.*

<table>
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<tbody>
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<td>SD</td>
</tr>
<tr>
<td>Error Management Training</td>
<td>0.79</td>
<td>0.24</td>
</tr>
<tr>
<td>Strategy Regulation Prompts</td>
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</table>

*N = 148.*
APPENDIX B: Full Literature Review

Changes in the nature of work, such as the shift away from repetitive and well-defined tasks toward increasingly novel and ambiguous tasks, require employees to be highly adaptable (Ilgen & Pulakos, 1999; Pulakos, Arad, Donovan, & Plamondon, 2000). The criticality of an adaptable workforce has created a greater need for improving training effectiveness in organizations. As training programs cannot prepare trainees for every possible situational contingency, they need to focus not only on providing individuals with a repertoire of relevant domain knowledge, but also preparing individuals to apply their knowledge and skills under novel conditions. Although traditional training approaches are beneficial for developing performance under routine conditions, training for performance under novel conditions requires a different approach to training design (Hesketh, 1997; Smith, Ford, & Kozlowski, 1997). One recent stream of research has focused on training interventions that increase adaptive transfer via self-regulatory processes (e.g., Bell & Kozlowski, 2008; Keith & Frese, 2005, 2008). Self-regulation refers to the processes an individual uses to achieve goal attainment, including controlling the direction and intensity of cognition, affect, and behavior (Kanfer & Kanfer, 1991; Karoly, 1993) and has been identified as a core theoretical construct underlying adaptability (Smith et al., 1997).

This line of adaptability research has identified some promising interventions and has confirmed the centrality of self-regulatory processes during training to improve adaptive transfer (e.g., Bell & Kozlowski, 2008; Keith & Frese, 2005). However, much of
this research has emerged separate from the literature on the nature of knowledge and skill acquisition. Most learning models describe knowledge acquisition as being characterized by different stages of learning (Anderson, 1982; Fitts & Posner, 1967; Schneider & Shiffrin, 1977), and self-regulatory processes have been shown to be differentially beneficial across these stages (Kanfer & Ackerman, 1989). This suggests that integrating self-regulatory interventions into training programs requires a dynamic perspective—one that takes into account which self-regulatory processes are important across the different stages of learning. As such, the goal of this study is to integrate the adaptability training literature with research on the nature of knowledge acquisition. Specifically, this study compares the effects of different sequences of self-regulatory training interventions on adaptive transfer. The findings from this study will contribute to the self-regulation and adaptability literatures by clarifying the relative importance of different self-regulatory mechanisms across different stages of knowledge acquisition as well as guide theory development on the role of self-regulation in adaptability training.

The following section presents an overview of adaptability, including the challenges of designing training to promote adaptive transfer. Then, two training approaches (error management training and prompting strategy regulation) that have received theoretical and empirical support for increasing adaptive transfer are presented with an emphasis on the mediating self-regulatory processes. Finally, the nature of knowledge acquisition is reviewed and integrated with research on training for adaptability.
Training for Adaptability

While many definitions of adaptability have been put forth in the literature (e.g., Banks, Bader, Fleming, Zaccaro, & Barber, 2001; Chan, 2000; LePine, Colquitt, & Erez, 2000; Ployhart & Bliese, 2006; Pulakos et al., 2000; White et al., 2005), these definitions all tend to agree that adaptability reflects a functional response in the face of changed environmental circumstances. As suggested by this definition, adaptability does not occur under routine conditions, but rather in response to, or anticipation of, novel or changed conditions (Ployhart & Bliese, 2006; White et al., 2005). Additionally, changing one’s response based on environmental conditions does not guarantee adaptability. Rather, the response must be functional—restoring the fit between an individual’s behaviors and the changed environmental circumstances (Banks et al., 2001; Chan, 2000; White et al., 2005). In describing the nature of adaptability, Chan (2000) noted that in situations requiring adaptability the “established and routine behaviors which were successful in the ‘old’ situations prior to the creation of new problems become irrelevant, ineffective, suboptimal, or less successful in the ‘new’ situation” (p. 6). This presents a rather unique challenge for training as most training paradigms focus on building expertise by automating a correct set of behaviors that are considered optimal under routine operating conditions (Hesketh, 1997; Kozlowski, 1998).

In understanding this training challenge, research has examined the nature of expertise. Specifically, researchers have distinguished between two types of experts: routine and adaptive (Hatano & Inagaki, 1986; Hatano & Osawa, 1983; Holyoak, 1991; Kozlowski, 1998). Routine experts maintain a high degree of procedural efficiency in
their domain (Hatano & Inagaki, 1986) and can perform quickly and accurately under a fixed set of operational parameters (Kozlowski, 1998). However, routine expertise can be a liability in dynamic work environments (Hesketh, 1997). Specifically, when operational parameters change—creating novel conditions—routine expertise can hinder performance as individuals may fail to recognize that changes in operational parameters have rendered their performance approach ineffective (Kozlowski, 1998; Smith et al., 1997; Sternberg & Frensch, 1992). These types of novel conditions require individuals to have adaptive expertise—exhibiting the core performance efficiencies of routine experts as well as the willingness and ability to detect environmental changes and modify performance strategies (Hatano & Inagaki, 1986; Holyoak, 1991; Kozlowski, 1998). Adaptive expertise is characterized by a deep understanding of which concepts in a domain are connected as well as how and why concepts are connected (Holyoak, 1991; Kimball & Holyoak, 2000; Kozlowski, 1998; Smith et al., 1997). This facilitates adaptive experts’ ability to detect relevant environmental changes and approach the situation from a different perspective—often drawing from their knowledge base to create new performance strategies under novel conditions (Holyoak, 1991; Kimball & Holyoak, 2000; Kozlowski, 1998; Smith et al., 1997).

Within the training domain, developing adaptability is operationalized through successful adaptive transfer (e.g., Bell & Kozlowski, 2008; Ivancic & Hesketh, 2000; Keith & Frese, 2005; 2008). Ivancic and Hesketh (2000) defined adaptive transfer as “using one’s existing knowledge base to change a learned procedure, or to generate a solution to a completely new problem” (p. 1968). Under conditions requiring adaptive
transfer, trainees must adjust their performance strategies to compensate for changes in the structural features of the task (Smith, 1996).

Successful adaptive transfer does not imply the same level of experience with the training domain as adaptive expertise (estimates suggest that achieving expert level performance in a domain requires thousands of hours of practice; Ericsson & Charness, 1994). However, the theoretical difference between adaptive expertise and routine expertise is the same as the difference between adaptive and analogical transfer (Ivancic & Hesketh, 2000; Smith et al., 1997). While analogical transfer refers to the routinized application of a learned procedure, adaptive transfer implies that the routinized application is not sufficient given the changed parameters and that successful transfer requires the trainee to modify the learned procedures (Ivancic & Hesketh, 1995/1996, 2000; Smith et al., 1997).

As noted earlier, preparing trainees to succeed under novel conditions requires a qualitatively different approach than training for performance under routine conditions (Hesketh, 1997; Smith et al., 1997). While trainees still need to have a firm understanding of the principles of the task domain (i.e., domain knowledge), they also need to develop skills to recognize changes in task demands, modify their task strategies, and evaluate the effectiveness of their new strategies (Ivancic & Hesketh, 2000). Specifically, researchers have suggested that training for adaptive transfer requires an emphasis on self-regulation to both foster the regulatory skills necessary for adaptability as well to increase trainees’ domain knowledge (Ivancic & Hesketh, 2000; Smith et al. 1997). Domain knowledge includes both basic knowledge (understanding fundamental information about a task) and
strategic knowledge (understanding the deeper complexities of a task such as when to use certain strategies; Bell & Kozlowski, 2002). Domain knowledge is critical for adaptive transfer as successful performance in novel situations requires both an understanding of the general facts and rules about a domain (i.e., basic knowledge) as well as an understanding of when and how to utilize different task strategies (i.e., strategic knowledge; Bell & Kozlowski, 2002; Kozlowski, 1998). This is consistent with research evidence showing basic and strategic knowledge to be important predictors of adaptive transfer (Bell & Kozlowski, 2008).

Self-regulation refers to a collection of processes (cognitive, affective, and behavioral) that facilitate individuals’ control over goal-striving activities (Kanfer & Kanfer, 1991; Karoly, 1993; Pintrich, 2000). As noted by Karoly (1993), these processes allow individuals to guide their “goal-directed activities over time and across changing circumstances” (p. 25). Effective self-regulation involves planning and goal setting, monitoring and evaluating goal progress, and adjusting strategies to facilitate reduction of goal discrepancies (Butler & Winne, 1995; Kanfer & Ackerman, 1989; Karoly, 1993; Pintrich, 2000). Engaging in self-regulatory processes during training leads to higher levels of post-training knowledge and research has identified self-regulation as particularly important in situations where trainees have control over their learning experience (e.g., active learning conditions) as it determines trainees’ distribution of effort between on-task and off-task activities (Bell & Kozlowski, 2008; Kanfer & Ackerman, 1989; Keith & Frese, 2005; Kozlowski & Bell, 2006; Schmidt & Ford, 2003).
In comparing the definition of self-regulation with that of adaptability, it is evident that effective self-regulation is necessary for adaptability, as an individual must be regulating to detect environmental changes, assess the effects of environmental changes on the current strategy, and adjust their strategies to align with the new environmental conditions (Bell & Kozlowski, 2008). The high degree of overlap between self-regulation and adaptability suggests that encouraging trainees to engage in self-regulatory processes during training is consistent with the principle of transfer-appropriate processing (Morris, Bransford, & Franks, 1977). Engaging in self-regulation during training allows trainees to practice the regulatory processes that they will need to engage to be successful under novel conditions (Ivancic & Hesketh, 2000). Given the need for adaptability in today’s workforce, it is not surprising that some have suggested that employees’ ability to self-regulate may be “their most essential asset” (Porath & Bateman, 2006, p. 185).

Training Interventions to Promote Adaptive Transfer

Researchers have examined a variety of training interventions designed to encourage different self-regulatory processes that theory suggests are important to promoting knowledge acquisition and adaptive transfer. In the current proposal, I have chosen to focus on two of these approaches: error management training (Keith & Frese, 2005, 2008) and prompting strategy regulation (Zaccaro, Conjar, Midberry, Ely, & Bryson, 2008; Zaccaro, Heinen et al., 2008). Each of these approaches and how they foster self-regulation, knowledge acquisition, and adaptive transfer are described in the following paragraphs.
Error Management Training

Error management training reflects an approach to training in which trainees are provided with minimal task guidance and are encouraged to actively explore the task domain in order to uncover the fundamental principles of the training task (Keith & Frese 2005, 2008). A hallmark of the error management training approach is that trainees are informed of the value of making errors and learning from their mistakes. Additionally, trainees are provided with error management strategies designed to mitigate the potential negative affect that might arise from making errors (Bell & Kozlowski, 2008; Dormann & Frese, 1994).

Past research suggests that error management training promotes trainees’ knowledge acquisition during training via two self-regulatory processes (Bell & Kozlowski, 2008; Keith & Frese, 2005). First, error management training encourages trainees to engage in metacognition (Keith & Frese, 2005). Metacognition includes cognitive regulatory activities related to the planning and monitoring of goal-directed behavior (Brown, Bransford, Ferrara, & Campione, 1983; Ford, Smith, Weissbein, Gully, & Salas, 1998). Trainees need to monitor their behavior in order to detect errors in their performance. After recognizing that an error has been made, the trainee then needs to understand the nature of the error and plan an alternate strategy (Ivancic & Hesketh, 2000). This process encourages trainees reflect on why their strategy did not work, resulting in a better understanding of the fundamentals of the task including general facts and rules about the domain (i.e., basic knowledge). Second, error management training assists trainees in regulating their emotions (Keith & Frese, 2005). Kanfer, Ackerman,
and Heggestad (1996) define emotion control as “the use of self-regulatory processes to keep performance anxiety and other negative emotional reactions (e.g., worry) at bay during task engagement” (p. 186). Managing emotions during training is considered to be essential to knowledge acquisition, as negative thoughts and emotions can consume valuable attentional resources (Kanfer & Ackerman, 1989). Especially during complex tasks, failures in emotion control reduce trainees’ attentional capacity and inhibit short-term memory processes necessary for learning (Wood, George-Falvy, & Debowsk, 1999). Trainees who experience negative emotions, such as dissatisfaction with their training performance, lose interest in training and become less willing to explore and experiment with the task (Bandura, 1997). Thus, error management training, with its emphasis on active learning and positive framing of errors, is thought to assist trainees in engaging in metacognition and emotion control, thereby increasing their basic knowledge levels.

In addition to promoting self-regulation and basic knowledge levels, research suggests that the regulatory processes encouraged by error management training contribute to adaptive transfer (e.g., Bell & Kozlowski, 2008; Keith & Frese, 2005). First, metacognition encourages trainees to repeatedly engage in a cycle of reflecting on errors and generating alternate strategies. As such, metacognitive activity during training builds foundational knowledge and facilitates the development of flexible knowledge structures, which are a necessary precursor for the development of adaptive expertise (Frese & Zapf, 1994). Second, exercising emotion control during training is also important for promoting adaptive transfer. Practicing maintaining emotion control in the face of errors is
important as it prepares trainees for performance in novel situations, such as not becoming anxious or frustrated when traditional performance strategies no longer apply (Keith & Frese, 2005). The following paragraphs review previous research that has examined the relationship between error management training and adaptive transfer.

Keith and Frese (2005) trained undergraduate students to create electronic presentation slides. In the error management condition, trainees were not provided with any instruction on how to achieve the task solution (exploratory learning) and were encouraged to make errors in training and to learn from those errors (error framing). In the control condition, trainees received detailed step-by-step instructions outlining how to create the electronic presentation slides and were not encouraged to make errors or to learn from their mistakes. After practicing the tasks, in the transfer trial, trainees had to recreate a set of electronic presentation slides that included a repetition of a function that was covered during the training (i.e., analogical transfer) and functions that were completely new and had not been covered in the training (i.e., adaptive transfer). While the two training groups did not differ on analogical transfer, trainees in the error management training condition performed significantly better on the adaptive transfer task (after controlling for pretraining computer knowledge). Providing support for the role of self-regulation in training on adaptive transfer, mediation analyses revealed that metacognition and emotion control fully mediated the effect of error management training on adaptive transfer.

Similarly, Bell and Kozlowski (2008) examined the effects of several training design elements (including exploratory learning and error framing) on self-regulatory
processes and adaptive transfer using a radar-tracking simulation task. Trainees in the exploratory learning condition were instructed to explore that task and use exploration and experimentation to understand how to perform the task, while trainees in the comparison group received step-by-step proceduralized instructions for performing the task. Trainees in the positive error framing condition were encouraged to make errors and to learn from their mistakes while trainees in the negative error framing condition were instructed to avoid making mistakes during training.

Exploratory learning and positive error framing both had positive effects on adaptive transfer. Additionally, trainees in the exploratory learning condition reported engaging in higher levels of metacognition during training.

Keith and Frese (2008) synthesized the results from 24 studies examining the relationship between error management training and analogical and adaptive transfer. Results from their analyses showed that while error management training led to significantly higher analogical transfer ($d = 0.20$), the effect was much stronger for adaptive transfer ($d = 0.80$). These results highlight the effectiveness of using error management training to prepare trainees to successfully perform in novel situations.

As described above, previous research has established a relationship between error management training and adaptive transfer. In examining the mediating mechanisms, research evidence suggests error management training encourages trainees to engage in metacognitive activities by monitoring their performance, noting gaps in their mental models, and trying to fill those gaps. Additionally, error management
training grows trainees’ abilities to control their emotions—especially in the face of frustrations such as errors.

**Prompting Strategy Regulation**

Researchers have suggested that to foster adaptability, training programs should provide specific “cues to engage in adaptive thinking,” such as prompting trainees to engage in behaviors to promote strategy regulation (Ely, Zaccaro, & Conjar, 2009, p. 179). As a training intervention, prompting strategy regulation includes periodically presenting trainees with questions to remind them evaluate the effectiveness of their current strategies and to consider if there are other strategies that they could use (Sitzmann et al., 2009; Zaccaro et al. 2008).

Although prior research has demonstrated that prompting strategy regulation increases important training outcomes, particularly adaptive transfer (e.g., Zaccaro, Heinen et al., 2008), it has not elucidated the self-regulatory mechanisms by which this intervention exhibits its effects. The current study proposes that prompting strategy regulation promotes trainees’ knowledge acquisition during training via two self-regulatory processes. First, prompting strategy regulation should encourage trainees’ to engage in hypothesis testing. Hypothesis testing refers to the strategies trainees use when making predictions about the task and refining their task strategies for successful performance (Smith, 1996). As trainees work to improve their performance, they do not try new performance strategies randomly. Rather their strategy refinement is based on their hypotheses about how the task works and is guided by their mental model of the domain (Bell, 2002; Grief & Keller, 1990). Trainees who engage in higher levels of
hypothesis testing tend to explore more performance strategies and have higher levels of strategic knowledge (Bell, 2002).

Second, prompting strategy regulation should increase training motivation. Training motivation refers to the “direction, intensity, and persistence of learning-directed behavior in training contexts” (Colquitt, LePine, & Noe, 2000; p. 678). Trainees use goals as reference points for evaluating their training progress and when trainees are prompted to refine their strategies to increase their training performance they should increase the intensity of their learning-directed behaviors. Additionally, challenging trainees to refine their strategies and increase their performance provides motivation to engage in the discovery and development of task-strategies (Locke & Latham, 2002). This increased motivation toward identifying and trying new performance strategies leads trainees to understand deeper task elements, such as understanding when and why to apply certain strategies (i.e. strategic knowledge). This is consistent with research findings from Sitzmann et al. (2009) who found that trainees who received the strategy regulation prompts had higher levels of strategic knowledge than trainees who did not receive the prompts. Trainees with high strategic knowledge have complex and integrated frameworks of the training domain, which is a precursor of adaptability (Bell & Kozlowski, 2008; Horn, 2008; Kozlowski & Bell, 2006; Smith et al. 1997).

In addition to hypothesis testing and training motivation influencing adaptive transfer via strategic knowledge, they should also influence adaptive transfer directly. Hypothesis testing during training is important for adaptive transfer as it provides the trainee with practice making hypotheses and predictions about the task, testing the
predictions, and experimenting with performance strategies to develop those that are optimal for task performance (Smith, 1996). Engaging in these behaviors is critical for detecting the misalignment between current strategies and operating conditions which catalyzes adaptive behavior (Zaccaro, 2008). After noticing a misfit between their current strategy and environmental conditions, trainees need to approach the problem from a different perspective or frame of reference (Horn, 2008; Zaccaro, 2008). When trainees are prompted to engage in strategy regulation, they are encouraged to experiment with multiple strategies, thereby approaching the task from multiple perspectives. Individuals use frames of references to interpret their environment (Jacobs & Jaques, 1987) and engaging in frame changing—integrating different frames of reference and perspectives to arrive at a new strategy—has been identified as critical to adaptability (Horn, 2008; Zaccaro, 2008).

Training motivation is also important for adaptive transfer. As noted earlier, training motivation includes the amount of mental effort directed to a task, and the extent to which mental effort is maintained over time (Kanfer & Ackerman, 1989). Under novel conditions motivation is important, as trainees must be motivated to engage in key regulatory behaviors such as monitoring environmental conditions and exploring new task strategies to meet the changed conditions. Past research has shown that training motivation has a significant influence on trainees’ motivation to transfer the skills learned in training (Martineau, 1995; Ramirez, 2000; Warr, Allen, & Birdi, 1999). This suggests that trainees who are more motivated during training will be more motivated to exert effort under conditions of adaptive transfer.
Prompting strategy regulation has been shown to be particularly potent when paired with experiential variety (Zaccaro, Heinen et al., 2008). Experiential variety includes the presentation of exercises or examples that differ significantly on core performance requirements (i.e., structural variation; Gick & Holyoak, 1987). Pairing prompting strategy regulation with experiential variety provides trainees with the opportunity to experience changing combinations of operational parameters and to consider the degree to which different strategies are successful under different scenarios (Ford et al., 1998; Zaccaro, Heinen et al., 2008). Thus, prompting strategy regulation during a dynamic task provides trainees with an understanding of how and when strategies apply to different types of problems, which is a cornerstone of adaptive expertise. The following paragraphs review previous research that has examined the relationship between prompting strategy regulation and adaptive transfer using dynamic tasks.

Smith (1996) encouraged trainees to regulate their strategies during a radar-tracking task. First, trainees were instructed on the importance of engaging in regulatory behaviors in order to perform successfully during training. Then, before each of the trainees’ practice sessions, trainees were instructed to monitor their task strategies and evaluate possible areas for improvement. Specifically, trainees were asked to identify where they had the most trouble in the previous practice round and identify the knowledge or skills that they wanted to focus on improving in the next practice round. Smith found that in both the active learning and guided discovery conditions, trainees who received the strategy regulation intervention exhibited higher levels of adaptive
transfer than trainees who did not receive the strategy regulation intervention.

Using a city management simulation, Zaccaro, Heinen et al. (2008) instructed trainees on how to engage in strategy regulation behaviors including monitoring the environment to detect changes that would impact the effectiveness of the current performance strategy, changing their perspectives to create a new strategy, and continually monitoring the effectiveness of their strategies. Additionally, periodically throughout the simulation, trainees were prompted to engage in strategy regulation by reflecting on the effectiveness of their current strategies and identifying if there were other strategies that might be more effective (i.e., hypothesis generation). Under conditions of scenario variability, Zaccaro, Heinen et al. found that in the adaptive transfer round, trainees who received the strategy regulation instruction and prompting, were more likely to make a highly adaptive decision than trainees who had not received the strategy regulation manipulation.

Zaccaro, Conjar et al. (2008) integrated strategy prompts into a dynamic scenario-based simulation to encourage trainees to reflect on their situational assessment (e.g., Have you gathered enough information to make a good decision?) and frame changing (e.g., Have you considered this problem from a different perspective?). Additionally, after making a decision, trainees were provided with feedback on the effectiveness of their strategy. In the transfer round (in which the prompts were removed), trainees who had received the prompts throughout training made more correct adaptive decisions than trainees who did not receive the prompts.
As outlined in the previous paragraphs, research has established a relationship between prompting strategy regulation and adaptive transfer. However, research has yet to examine the mediating mechanisms through which strategy regulation prompts influence adaptive transfer. This study will examine hypothesis testing and training motivation as the mediating regulatory processes that predict strategic knowledge and adaptive transfer. Specifically, strategy regulation prompts direct trainees to engage in hypothesis testing by encouraging them to formulate and test alternate performance strategies. Additionally, prompting strategy regulation should assist trainees in remaining motivated as they strive to improve their training performance. Finally, higher levels of hypothesis testing and training motivation lead to higher levels of strategic knowledge, which is critical for adaptive transfer (Bell, 2002).

Self-Regulation and Stages of Knowledge Acquisition

As described above, the body of evidence resulting from this research suggests that these training interventions promote learning and facilitate adaptive transfer via their effects on self-regulatory processes (Bell & Kozlowski, 2008; Keith & Frese, 2005). However in looking across adaptability training research, most studies implement the same intervention across the entire training course (e.g., Bell & Kozlowski, 2008), despite evidence that some self-regulatory processes are differentially important in early and late knowledge acquisition (Kanfer & Ackerman, 1989, 1990). Specifically, Kanfer and Ackerman suggest that self-regulatory factors related to emotion control (e.g., reducing negative emotions after making errors) are important in early stages of knowledge acquisition while processes related to motivation control (e.g., increasing
effort devoted to the task) is important during the late stages of knowledge acquisition. As such, research is needed to better understand if sequencing training interventions across different stages of knowledge acquisition will increase adaptive transfer. The following paragraphs discuss the different stages of knowledge acquisition and highlight the relevant self-regulatory processes and interventions across the different stages (see Figure 3 for summary).

The nature of knowledge acquisition is a complex and dynamic process. Most learning theories describe knowledge acquisition as being comprised of different stages of learning that begin with resource dependency and end in skilled performance (Anderson, 1982; Fitts & Posner, 1967; Schneider & Shiffrin, 1977). The early stage of learning is characterized by high cognitive demands as trainees work to understand task instructions, familiarize themselves with task goals, and formulate strategies for task accomplishment (Ackerman, 1992; Fitts & Posner, 1967; Weiss, 1990). According to Kanfer and Ackerman (1989), the early stage of knowledge acquisition requires “substantial attentional resource demands” (p. 660) as trainees work to understand and perform the task.

In addition to the early stage of learning being the most cognitively demanding, it also has a large affective component. As trainees are facing a novel and unfamiliar environment, they are likely to experience increased anxiety. This early stage of knowledge acquisition is also when the task appears the most daunting and trainees are likely to make the most mistakes (Kanfer & Ackerman, 1989, 1996; Weiss, 1990). Making mistakes in training can lead to frustration and negative affect (Frese & Altman,
From a resource allocation perspective (Ellis & Ashbrook, 1988; Kanfer & Ackerman, 1989), negative affect such as anxiety and frustration are disruptive to learning as they divert attentional resources toward off-task thoughts, leaving fewer resources available to direct toward the task.

Cognitive psychology research suggests that expertise requires the possession of a large body of domain knowledge (Wiley, 1998). However, in achieving expertise, it is critical to not only acquire a large quantity of knowledge, but also to structure it in such a way that it is accessible, proceduralized, and integrated with other knowledge structures (Bédard & Chi, 1992; Ericsson & Charness, 1994). Specifically, to form an integrated representation of the domain, learning activities should be sequenced such that basic knowledge is built prior to more complex strategic knowledge (Bell & Kozlowski, 2002; Gagné, 1985). As such, when designing a training curriculum that promotes adaptive transfer, it is critical to employ training designs that focus on providing trainees with a foundational knowledge base in the early stages of training programs.

As described above, during the early stage of knowledge acquisition, trainees need to focus their cognitive resources toward building their foundational knowledge by understanding the basic principles of the task while limiting the rise of negative affect resulting from making errors. This suggests that training interventions that promote trainees’ active task exploration and emotion control, such as error management training, would be beneficial early in training. Error management training leads trainees to persist on new and difficult tasks and reduces the negative emotional effects of making errors during training (Heimbeck, Frese, Sonnentag, & Keith, 2003). Error management training
also promotes trainees’ active exploration of the task—including making errors and learning from those errors—which promotes a more accurate mental model of the task domain (Kozlowski, Gully et al. 2001). Additionally, highlighting errors as learning opportunities has been associated with promoting trainees’ to adopt a mastery goal orientation (Bell & Kozlowski, 2008), which has been suggested to buffer trainees from becoming demotivated when they had performance difficulties (Colquitt & Simmering, 1998).

As such, error management training should be incorporated early in the curriculum as it encourages active exploration of the principles in the training domain and facilitates the integration of new information within trainees’ existing knowledge structures (Smith et al., 1997). Additionally, as this early stage of skill development is particularly error prone (Kanfer & Ackerman, 1989), error management training decreases the likelihood that trainees will become frustrated when they make errors—thereby mitigating the negative motivational consequences generally associated with making errors (Ivancic & Hesketh, 1995/1996).

Given the substantial attentional resource demands that are required during this early stage of skill acquisition (Kanfer & Ackerman, 1989), it is possible that prompting trainees to engage in strategy regulation at this stage may create cognitive overload. Additionally, for complex tasks, learning should be sequenced to focus on the fundamentals before proceeding to the strategic aspects of the task (Bell & Kozlowski, 2002; Reigeluth, Merrill, Wilson, & Spiller, 1980). As prompting strategy regulation targets strategic knowledge—which is built on top of basic, foundational knowledge—
encouraging trainees to focus on refining tasks strategies early in training, before they have learned the basics of the task, may be counterproductive as it redirects trainees’ attention away from building basic knowledge.

As learning advances beyond initial acquisition phases, several changes in processing occur as a function of continued practice (Anderson, 1982). First, trainees begin to focus less on declarative knowledge and more on procedural knowledge. This leads to task automation (Schneider & Shiffrin, 1977) as trainees move through the compilation and procedural phases of knowledge acquisition (Anderson & Fincham, 1994). Additionally, as trainees learn more about the task, performance becomes faster and less error prone—resulting in less of a need for emotion control to combat the frustration and negative affect that accompanies error making (Kanfer & Ackerman, 1996). Taken together, this suggests that the benefits of error management training (increased metacognition and emotion control) for knowledge acquisition decrease in later stages of knowledge acquisition because trainees have already learned the foundations of the task and are not making as many errors as they were early in training.

As trainees gain task experience through repeated practice, their knowledge about the domain becomes meaningfully structured in memory (Kraiger, Ford, & Salas, 1993). In the progression from novice to expert, trainees’ knowledge structures tend to become broader and deeper, with novices attending to surface features while experts attend to deeper structural features (Chi, Feltovich, & Glaser, 1981). Additionally, as noted by Gagné and Medsker (1996), during the later stages of knowledge acquisition, trainees become more adept at determining the appropriate situations for skill use. This suggests
that trainees are better equipped to focus on building higher-order strategic knowledge through hypothesis testing in the latter stages of training, after they have learned the fundamentals of the task (Ackerman, 1987; Anderson, 1982; Fitts & Posner, 1967). As such, trainees with more domain knowledge should benefit from prompting strategy regulation as they have the requisite knowledge base to be able to attend to the structural features of the task, while novices may only be able to regulate around basic surface features.

During the later stages of training, trainees tend to cognitively withdraw due to fatigue and a belief that they have mastered the task (Bell & Kozlowski, 2002). If trainees perceive that their skill level is acceptable, instead of remaining motivated to refine their task strategies they may limit the intensity of their effort, thereby failing to achieve an optimal level of performance (Bell & Kozlowski, 2002; Kanfer & Ackerman, 1996). This is consistent with research evidence suggesting that trainees’ motivation tends to decrease across training (Sitzmann et al., 2009). To combat this effect, late in training, trainees should benefit from interventions that motivate trainees to continue to engage in learning-directed behaviors. Prompting strategy regulation encourages trainees to remain motivated, to persist at refining their task strategies, and to continue exploring new strategies to increase their performance.

Summary

The proposed study integrates the literature on the nature of skill acquisition with research on training interventions designed to promote adaptability. While previous research has demonstrated the effectiveness of error management training and prompting
strategy regulation on promoting adaptive transfer (Bell & Kozlowski, 2008; Keith & Frese, 2005; 2008; Zaccaro, Conjar et al., 2008; Zaccaro, Heinen et al., 2008), research has not yet examined the effects of sequencing these interventions to promote different regulatory processes across the stages of knowledge acquisition. It is proposed that during the early stage of knowledge acquisition—which is cognitively demanding and error prone—trainees benefit more from error management training than prompting strategy regulation. Error management early in training is hypothesized to promote metacognitive activity and emotion control and build trainees’ basic knowledge about the task—all of which contribute to successful adaptive transfer. Conversely, late in training, when trainees have a foundational knowledge about the task, trainees should benefit more from strategy regulation prompts than error management training. Being prompted to engage in strategy regulation is hypothesized to promote adaptive transfer by increasing hypothesis testing and training motivation and building trainees’ strategic knowledge about the task. Thus, it is hypothesized that trainees receiving error management training early in training and strategy regulation prompts late in training will have higher levels of adaptive transfer than trainees that receive error management or strategy regulation prompts throughout training or than trainees who received strategy regulation prompts early in training and error management training late in training. The results from this study will contribute to research on training for adaptive transfer by providing initial evidence of the relative importance of different self-regulatory processes across the stages of skill acquisition and an understanding of the degree to which encouraging these processes at different points during training contributes to adaptive transfer.
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