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Adaptive Guidance: Enhancing Self-Regulation, Knowledge, and Performance in Technology-Based Training

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Abstract

Considerable research has examined the effects of giving trainees control over their learning (Steinberg, 1977, 1989; Williams, 1993). The most consistent finding of this research has been that trainees do not make good instructional use of the control they are given. Yet, today's technologically based training systems often provide individuals with significant control over their learning (Brown, 2001). This creates a dilemma that must be addressed if technology is going to be used to create more effective training systems. The current study extended past research that has examined the effects of providing trainees with some form of advisement or guidance in addition to learner control and examined the impact of an instructional strategy, adaptive guidance, on learning and performance in a complex training environment. Overall, it was found that adaptive guidance had a substantial effect on the nature of trainees' study and practice, self-regulation, knowledge acquired, and performance.

Keywords

adaptive guidance, self-regulation, training, technology, performance

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Social and Behavioral Sciences

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Abstract

Considerable research has examined the effects of giving trainees control over their learning (Steinberg, 1977, 1989; Williams, 1993). The most consistent finding of this research has been that trainees do not make good instructional use of the control they are given. Yet, today's technologically based training systems often provide individuals with significant control over their learning (Brown, 2001). This creates a dilemma that must be addressed if technology is going to be used to create more effective training systems. The current study extended past research that has examined the effects of providing trainees with some form of advisement or guidance in addition to learner control and examined the impact of an instructional strategy, adaptive guidance, on learning and performance in a complex training environment. Overall, it was found that adaptive guidance had a substantial effect on the nature of trainees' study and practice, self-regulation, knowledge acquired, and performance.

The Effects of Adaptive Guidance in a Complex Training Environment

Advanced computer-based technologies have created a vast range of opportunities to create new training tools. As the cost of these technologies declines, an increasing number of organizations are beginning to implement technologically based training applications, such as simulations, web-based training, and distance learning. These applications offer many advantages. For example, they can create a safe training environment for individuals to learn tasks on which actual mistakes can result in serious injury or extensive damage to equipment. By allowing training to occur almost anywhere and at anytime, these applications are also very well suited for today's global companies and their dispersed employees. Perhaps the most frequently cited advantage of these emerging computer-based technologies, however, is that they allow learners to have considerable control over different aspects (e.g., content, sequence, pace) of their learning process.

In the past, computer-based instruction was often used to reduce or eliminate trainees' control over various learning decisions (e.g., Tennyson, 1980, 1981). Today's advanced training technologies, however, provide individuals with an unprecedented degree of control over their learning. In web-based training, for example, individuals can use hyper-links and menus to customize the material to which they attend, determine the sequence by which they learn, and control the amount of time they spend on a particular topic. In distance-learning applications, individuals are able to participate in training at their convenience and with little or no supervision. The learner control inherent in these applications is typically perceived as a positive feature that will enhance motivation and, therefore, increase learning and performance (Reeves, 1993). However, research on learner control conducted over the last three decades has typically failed to reveal this motivational advantage. Instead, research has shown that learner control is associated with a number of negative outcomes, such as less time spent on-task and the use of poor learning strategies (Brown, 2001; Steinberg, 1977, 1989; Williams, 1993). In addition, these negative effects have often been found in studies using fairly simple learning tasks; today's often cognitively complex and dynamic training environments may make it even more difficult for trainees to effectively utilize learner control.

This situation creates a training dilemma. The nature of advanced training technologies is such that they offer trainees significant control over their learning. Yet, research has shown that learner control is often an ineffective instructional strategy, and may be even more so when dealing with complex, dynamic, and multidimensional learning tasks. There is the potential for organizations to develop technologically based training programs that are cost efficient and practical, but ineffective. It is critical, therefore, to design instructional techniques that assist trainees in making effective use of the control they are given. As Brown (2001, p.293) states, "In coming years, as responsibility for learning is shifted from trainers to learners, how organizations deal with variability in learners and learner choices will become an increasingly important determinant of overall training effectiveness."

The current study examines an instructional strategy, adaptive guidance, which is designed to assist trainees in making effective learning decisions. Adaptive guidance was developed by extending past research on a variety of advisement strategies (Tennyson, 1980; 1981; Tennyson & Buttrey, 1980; Tennyson & Rothen, 1979). It is based on a self-regulatory approach to training effectiveness (Kozlowski, Toney, Weissbein, Brown, & Bell, 2001) and is designed to be appropriate for more complex training environments that require individuals to acquire, integrate, apply, and generalize a complex set of basic and strategic concepts. In the following section, we describe adaptive guidance, discuss its theoretical foundation, and highlight its potential applicability to training cognitively complex tasks.

Adaptive Guidance

Overview. Adaptive guidance is training strategy that provides trainees with diagnostic and interpretive information that helps them make effective learning decisions. Past research has shown that trainees given control over their learning often make poor learning choices, such as terminating study and practice early and skipping over important learning opportunities (e.g., Brown, 2001). Therefore, adaptive guidance is designed to provide trainees with information regarding future directions that should be taken for improvement. A great deal of research has focused on feedback as a means of providing trainees with information about their prior performance (see Kluger & DeNisi, 1996). Although feedback interventions can differ on a number of dimensions, at a basic level most are targeted toward providing individuals with descriptive and evaluative information about their prior performance. The value of this information for enhancing performance depends on how it is interpreted by the recipient and, in turn, influences future task and learning decisions (Ilgen, Fisher, & Taylor 1979). However, this interpretation process is typically uncontrolled in training, which may make it difficult for trainees to evaluate their performance and determine future actions that should be taken for improvement (Kozlowski, Toney et al., 2001). In fact, feedback can actually hurt performance if it is misintepreted and directs attention away from task-learning processes (Kluger & DeNisi, 1996). Thus, while it can serve as a critical foundation for learning, the ability of feedback alone to enhance the process of learning has been questioned, particularly on more unfamiliar and complex tasks (Balzer, Doherty, & O'Connor, 1989; Kluger & DeNisi, 1996).

Adaptive guidance, therefore, is designed to augment the interpretation process with future oriented information that will enhance self-regulation in learning. It provides information that helps trainees not only interpret the meaning of their past performance but also determine what they should be studying and practicing to achieve mastery. Adaptive guidance does not take the place of feedback, but rather supplements it by providing additional information that trainees need to make effective decisions about how best to deploy their attentional resources and allocate their effort. As a result, with adaptive guidance individuals should be better equipped to make effective learning choices.

Adaptive guidance is also tailored to meet the differing needs of individual trainees. It utilizes computer technologies to monitor and assess individuals' progress, and provides trainees with recommendations based on these evaluations. Guided information describes what a trainee should think about and how to think about it (e.g., metacognitive strategies; Nelson, Dunlosky, Graf, & Narens, 1994) and the behaviors a trainee should next engage in (Early, Connolly, & Ekegren, 1990). In addition, adaptive guidance focuses on not only the content but also the sequence of trainees' study and practice. The sequence in which task information is encoded is critical because it determines the extent to which concepts are integrated to form a comprehensive representation of the task domain (Gagné, 1985). Learning is a gradual process in which the acquisition of difficult and complex skills and knowledge depends on the degree to which one has previously learned more fundamental or basic skills and knowledge. Poor sequencing of learning can inhibit the acquisition of critical skills and knowledge. Therefore, as trainees master more fundamental knowledge and skills, adaptive guidance is designed to adjust to their level of acquisition and instruct them to focus attention on increasingly advanced knowledge and skills.

<u>Extending advisement.</u> Past research has generally shown that guiding individuals through computer-based instruction is more effective than providing either total learner control or total program control (e.g., Santiago & Okey, 1992; Tennyson, 1980; Tennyson & Buttrey, 1980). Research on learner control, for example, has consistently shown that individuals are not good judges of what or how much they need to learn and practice (Tennyson & Rothen, 1979; Tennyson, 1980; Williams, 1993). As a result, individuals typically perform better under program control conditions in which the computer makes important learning decisions, such as what and how much to practice (Tennyson, Tennyson, &

Rothen, 1980). However, studies have also shown that computer control eliminates many of the advantages associated with learner control. For example, students' attitudes toward instruction are often more negative under computer control because they no longer have a sense of control over their learning process (Park & Tennyson, 1983; Tennyson & Buttrey, 1980). In addition, computer control is difficult and time consuming to implement because it requires computer programs that can handle the myriad and complex types of branching that can occur in a lesson.

Research has shown that guiding or advising individuals as they progress through training combines many of the advantages offered by both learner and program control (Tennyson, 1980). With advisement, individuals are provided with information necessary for making effective learning decisions, but choose whether and how to make use of the information. They tend to retain a sense of control over their learning while also exhibiting performance similar to that found under program control (Tennyson, 1980; Tennyson & Buttrey, 1980; Santiago & Okey, 1992). Although advisement appears to offer many benefits, it has typically been evaluated using relatively simple, static, and unidimensional learning tasks. As a result, it is difficult to make firm predictions regarding the potential effectiveness of advisement in more cognitively complex and challenging training environments.

Adaptive guidance as a training strategy is based on a foundation provided by advisement research, but utilizes self-regulation as a theoretical foundation, and is designed to extend to more cognitively complex domains that necessitate integration between both cognitive and procedural skills. Adaptive guidance is designed to influence trainee interpretation of feedback by providing information that enhances the quality and focus of trainee self-regulation (Kozlowski, Toney et al., 2001). Self-regulation is a core theoretical process underlying learning (Kanfer, 1990a, 1990b) and, although there are many self-regulatory models, most address three related sets of activities—self-monitoring, self-evaluation, and self-reactions. Adaptive guidance is designed to influence self-evaluation by helping trainees to calibrate current progress toward task mastery, which should influence the amount of effort they invest in learning. It is designed to influence self-monitoring by providing suggestions for what trainees should study and practice—based on progress—which should influence their allocation of attention to current knowledge and performance deficiencies. In addition, as trainees acquire basic knowledge and skills, adaptive guidance is designed to shift trainee monitoring to more advanced or strategic aspects of the task. Finally, adaptive guidance is designed to influence self-reactions in the form of self-efficacy. By helping trainees to interpret meaningful progress toward task mastery, they should have an improved sense of capability to deal with future task demands and challenges. Thus, by helping trainees to interpret their current progress, and by suggesting a sequence of learning objectives as knowledge and skills improve, adaptive guidance is designed to focus trainee attention and effort to promote more effective learning. Key features distinguishing advisement and adaptive guidance are summarized in Table 1.

Insert Table 1 about here

The first two instructional features presented in Table 1 are essentially the same for both advisement and adaptive guidance. Advisement provides learner control over various aspects of instruction (e.g., sequence, content, pace) and uses trainees' past performance to suggest examples or instances to study. In Tennyson (1980), for example, students learned a number of concepts from the field of physics (e.g., velocity) by answering example questions on each concept and receiving feedback on whether their responses were correct or incorrect. Based on their performance on these sample questions, the advisement *recommended* the number of examples students needed to answer to achieve mastery on each concept. Adaptive guidance provides similar learner control and prescriptive information, although suggestions target specific learning content and procedural skills.

Beyond this similar foundation, adaptive guidance represents an elaboration and extension of advisement. The recommendations provided by advisement are typically undimensional. For example, a student exhibiting poor performance on sample items or examples is simply told to review more examples. Thus, advisement is designed to improve declarative knowledge by emphasizing repetition to enhance encoding and retention. In contrast, the suggestions provided by adaptive guidance are multidimensional and focus on both cognitive and skill-based task components. Rather than suggesting the number of examples or instances that should be reviewed, adaptive guidance suggests content that trainees should study and skills that trainees should practice to achieve mastery. As a result, adaptive guidance is designed to not only facilitate the encoding of information but also to promote the integration of concepts and the development of task strategies. In a recent study by Brown (2001), for example, employees participated in a computer-based training program designed to teach a standardized problem-solving process. The course materials included text, graphics, and interactive activities for practice, and trainees had total control over the material they studied and the activities they practiced. Brown (2001) found that many individuals made poor learning choices, which, in turn, limited the knowledge they gained. Adaptive guidance could be incorporated into this program to supplement feedback by diagnosing individuals' progress and, based on this information, recommending specific material that trainees should be studying and activities they should be practicing to achieve mastery on each of the instructional objectives. This information should help individuals to make better learning choices and, as a result, enhance training effectiveness.

Diagnostic information provided by advisement is limited because students can only infer their current progress by the amount of instruction that is recommended. Adaptive guidance, on the other hand, provides evaluative information that allows trainees to better calibrate discrepancies between current and desired levels of performance. For example, in the Tennyson (1980) study, trainees were provided recommendations on how many examples they should review to learn each of the physics concepts. Adaptive guidance, however, would provide specific information concerning the extent to which a trainee had learned each of the concepts, which would enable trainees to better determine where they should be focusing their attention and effort.

Finally, because advisement is primarily focused on the acquisition of declarative knowledge, the material is not typically organized or sequenced. That is, task content is not connected or integrated in a logical and developmental fashion. Although advisement has sometimes been used to group similar concepts during instruction (e.g., Tennyson 1980; Tennyson et al., 1980), it has not been used to focus trainees' attention on learning the fundamental aspects of a task before progressing to more complex task components (Wood, Kakebeeke, Debowski, & Frese, 2000). Adaptive guidance not only groups similar topics but also sequences task content so that trainees learn fundamental aspects of the task early in training and gradually transition to more strategic or complex aspects of the task as basic skills are acquired. For example, Wood et al. (2001) taught individuals how to conduct CD-ROM database searches. Before learning more complex search strategies, individuals needed to learn the more fundamental skill of identifying relevant keywords using the thesaurus and keyword index. Advisement would not sequence these learning activities, whereas adaptive guidance would focus individuals' study and practice early in training on identifying keywords and would transition to learning how to incorporate these keywords into complex searches later in training. This sequencing should serve to both build self-efficacy early in training and maintain challenge and interest during the later stages of training (Wood et al., 2000).

<u>Addressing the limitations of past research.</u> In addition to extending advisement as a training strategy, the current study is also designed to address several limitations that have characterized past

research on advisement. A major limitation of past research on learner control and advisement is that most studies have been conducted using relatively simple, static learning tasks (Reeves, 1993). The most common paradigm has been to have students learn (i.e., memorize) a set of concepts. Topics covered in lessons have included solar energy and tarantulas (Kinzie & Sullivan, 1989), determining the surface area of hollow figures (McGrath, 1992), and learning concepts from physics (Tennyson, 1980) or psychology (Tennyson et al., 1980). The relative simplicity of these tasks is reflected by the average amount of time spent on-task by students in these studies. In a review of computer-based instruction, Reeves (1993) noted that most learner control studies reported completion times of under 30 minutes. For example, McGrath's (1992) students averaged 13-17 minutes in their treatments and Tennyson's (1980) students in the advisement condition spent an average of 10.3 minutes on task and those in the learner control condition averaged 7.7 minutes on task. Due to the relatively simple nature of these tasks, it is difficult to know whether the positive effects of advisement will transfer to more complex training environments.

In addition to using simple learning tasks, the instructional treatments employed in these studies have been criticized on several other grounds. Due to the short duration of these studies, for example, most often there has only been a single administration of the instructional treatment (Reeves, 1993). Cronbach and Snow (1977) have suggested that ten or more separate interactive sessions are necessary to acquaint students with innovative instructional treatments. Similarly, Reeves (1993) suggests that it is important to expose students to multiple treatments, "especially when researchers are seeking to detect the effects of the treatment on complex, difficult-to-measure variables such as learning and curiosity" (p. 42). In addition, the advisement provided in prior studies has typically focused learners' attention on *how much* to study and practice rather than *what* to study or practice (Reeves, 1993; Williams, 1993). Though, perhaps, useful, there is relatively little theoretical value in the knowledge that more practice leads to better learning. For more complex tasks, there is greater interest in impacting the quality of learning.

A final limitation centers on the dominant focus of past research on a single dependent measure, post-test performance (e.g., declarative knowledge). Post-test performance in these studies is often a flawed measure due to the fact that the post-test performance measures are usually in the same form as the examples provided during instruction. As a result, learning and performance are confounded and it is impossible to know whether trainees are able to transfer the knowledge and skills they have acquired to similar and more complex tasks. There has also been little attention directed toward understanding how advisement influences the content and sequence of students' instruction and how these instructional choices translate into learning outcomes or how advisement influences the affect of learners as they progress through training (Reeves, 1993). Finally, prior research has often failed to control for individual differences, such as ability, that may impact the processes and outcomes under examination.

Research goals. The purpose of this research is to examine the effects of adaptive guidance while simultaneously addressing the limitations discussed above. In the current study, adaptive guidance is used to direct the training of individuals on a complex and dynamic task. The adaptive guidance is administered over ten trials and is aimed not at having trainees study and practice more, but rather to study and practice better. In an attempt to better understand the manner in which advisement exerts effects, we measure the impact of adaptive guidance on multiple learning processes and outcomes and do so at three separate points in time. In addition, we examine the effect of guidance on these outcomes over and above the effects of cognitive ability. Overall, we believe that this study advances past research by providing a more appropriate indication of whether or not advisement holds potential as a useful supplement to today's advanced training technologies.

Hypotheses and Preliminary Model

Overview

Our conceptualization of adaptive guidance builds on the foundation of advisement research but also attempts to extend the relevance of the concept to more complex, dynamic, and multifaceted (knowledge and procedural skill) task domains. As a critical first step, it is important to map the main effects of adaptive guidance across a broad range of process and outcome variables that capture important aspects of the training process. Thus, we first focus on the theoretical rationale and predictions relevant to explicating the anticipated effects of adaptive guidance on indicators of training processes and outcomes.

However, another key limitation of advisement research has been the lack of a theoretical framework articulating the means by which advisement exhibits its effects. In this initial research, we take a step toward the development of such a framework. Based on the theoretical rationale specified in our prediction of main effects, we take the further step of proposing a model to capture the processes by which adaptive guidance exerts its effects on performance and generalization outcomes. Given the relative absence of research on these potential mediating processes, we consider this aspect of the research preliminary in nature.

In the following section, we develop direct effect hypotheses that were examined in the current study. We first discuss the potential impact of adaptive guidance on process variables, such as self-efficacy, on-task cognition, and study and practice sequence. We then hypothesize the relationship between adaptive guidance and trainees' learning and performance. Based on this rationale, we present a preliminary model that delineates the means by which we believe adaptive guidance has its effects. This model is designed to specify in more detail not only the paths by which adaptive guidance ultimately affects learning and performance but also the temporal nature of these relationships.

Direct Effects

Process variables. Considerable research in recent years has identified self-efficacy as a critical factor that influences individuals' learning and performance (e.g., Locke & Latham, 1990; Phillips & Gully, 1997). Self-efficacy is an individual's belief about whether he or she can perform a task or behavior and can be thought of as competency beliefs one holds about oneself. It is partly on the basis of self-efficacy that individuals choose what challenges to undertake, how much effort to expend in an endeavor, and how long to persevere in the face of difficulties (Bandura, 1982, 1986). Increased levels of self-efficacy typically lead to higher levels of learning and performance (e.g., Cervone, 1989; Locke & Latham, 1990; Kozlowski, Gully, Brown, Salas, Smith, & Nason, 2001; Phillips & Gully, 1997).

Past performance on a task is considered to be the best indicator of future performance (Gist & Mitchell, 1992; Silver, Mitchell, & Gist, 1995). Successful experiences tend to lead to increases in self-efficacy; failures undermine it. On difficult and complex tasks, individuals often make a number of errors, especially during the early stages of learning. Whereas feedback informs individuals of their performance deficiencies, adaptive guidance supplements this information by providing information on how to overcome these deficiencies. This information should act to increase individuals' beliefs that they can achieve the standards they are pursuing. Therefore, we posit that adaptive guidance will lead to higher levels of self-efficacy. Further, we believe that the positive effect of guidance on self-efficacy will be greatest during the early stages of training when individuals are likely to experience more errors and lower performance.

Hypothesis 1: Adaptive guidance will have a significant positive effect on individuals' self-efficacy, especially during the early stages of training.

In most training situations, some positive relation between task persistence and performance success exists, and most people believe that greater effort will result in improved performance (Sandelands, Brockner, & Glynn, 1988). A number of different factors, including the nature of the task and available opportunities for success, can influence individuals' perceptions of this persistence-performance relationship, and subsequently their decisions to put forth effort on a task. For example, during the early stages of learning a complex task, performance often involves many errors and the majority of feedback is likely to be negative. In these situations, individuals may perceive future effort to be futile or may withdraw effort in an attempt to protect their "competence image" (Jones, 1989). Individuals may also withdraw during the latter stages of learning due to fatigue, continued frustration, or the belief that they have mastered the task. The general idea behind theories of persistence is that individuals will be more likely to persist at a task if they believe they can achieve desired outcomes.

As mentioned earlier, one of the greatest benefits of advisement is that it increases individuals' time on task. Adaptive guidance should have a similar effect by providing individuals with prescriptive information about what they should study and practice to improve their performance on the task. Such information should serve to create the perception that the persistence-performance relationship is positive and continuous. Therefore, we believe that adaptive guidance will lead to greater task persistence, as measured by trainees' on and off-task cognition (Kanfer, Ackerman, Murtha, Dugdale, & Nelson, 1994). Measuring trainees' on-task cognition provides a more accurate assessment of trainees' task persistence than time-on-task because individuals may withdraw mentally from a task long before they actually quit physically performing it (Kanfer et al., 1994). This is especially true when individuals are required to spend a certain amount of time in training, as they were in the current study. We argue that the positive impact of adaptive guidance on trainees' on-task cognition will be greatest during the later stages of training, when individuals are not only fatigued but also more likely to believe they have mastered the task and have nothing to gain from continued effort.

Hypothesis 2: Adaptive guidance will have a significant and positive effect on trainees' on-task cognition, especially during the later stages of training.

There is little question that effort has a large impact on individuals' learning and performance. However, effort alone is often not enough to perform well on difficult and complex tasks. Individuals must also focus their effort on relevant aspects of the task. On complex tasks, it is necessary to appropriately sequence learning (Reigeluth, Merrill, Wilson, & Spiller, 1980); the trainee must first learn fundamental task skills. Once these skills are developed, the trainee can then proceed to learn the more advanced, strategic aspects of the task. Without fundamental skills, a trainee will be unable to learn more complex skills and will not perform well. Therefore, learning and performance are enhanced when trainees follow a ramped sequence of study and practice (Kozlowski, Toney et al., 2001). Adaptive guidance is aimed at helping trainees to appropriately sequence their study and practice. It focuses trainees on the fundamental aspects of the task early in training. As they become proficient in these areas, it transitions their study and practice to more advanced aspects of the task. As a result, adaptive guidance should lead to a more appropriate sequencing (fundamental – complex) of study and practice. The appropriate ramped sequence of study and practice for this task is presented in Figure 1.

Insert Figure 1 about here

Hypothesis 3: Trainees who receive adaptive guidance will be significantly more likely than other trainees to exhibit a ramped study sequence (fundamental – complex).

Hypothesis 4: Trainees who receive adaptive guidance will be significantly more likely than other trainees to exhibit a ramped practice sequence (fundamental – complex).

Outcome variables. Learning is an outcome variable that is often forgotten in training studies (Kraiger, Ford, & Salas, 1993). In situations involving complex and dynamic tasks, learning can often be broken down into two components, basic and strategic knowledge.

Basic knowledge refers to the extent to which a trainee has learned the fundamental principles and operations of a task. It involves both declarative knowledge (information on *what*) and procedural knowledge (information about *how*) (Ford & Kraiger, 1995; Tennyson & Breuer, 1997). For example, in the study by Wood et al. (2000) described earlier, one aspect of basic knowledge would involve learning how to use to the thesaurus and keyword index to identify relevant keywords. Strategic knowledge, on the other hand, refers to the extent to which a trainee has learned the underlying or deeper complexities of a task. Strategic knowledge goes beyond memorization and requires participants to integrate important task concepts and develop and test task strategies. Although this type of knowledge has been given several names, including strategic, tacit, and contextual knowledge, the core idea is that this type of knowledge involves information on *which, why, when, and where* to apply one's knowledge and skills (Ford & Kraiger, 1995; Gagné & Merrill, 1992; Tennyson & Breuer, 1997). For example, in the Wood et al. (2000) study strategic knowledge involved knowing how to link concepts to increase the depth and breadth of a search. The basic process of identifying keywords still applied; however, trainees needed to develop search strategies to increase the number of relevant records retrieved. They also needed to know how to modify these strategies depending on the results of their preliminary searches.

We examined the effect of adaptive guidance on both forms of knowledge. Based on individuals' past performance, adaptive guidance suggests future plans of study. It also assists trainees in the sequencing of their study, so that they focus on learning fundamental aspects of the task first and then gradually shift to the more complex aspects of the task once a strong knowledge base has been formed. As a result, we posit that adaptive guidance will have a positive effect on trainees' basic knowledge early in training, and their strategic knowledge later in training.

Hypothesis 5: Adaptive guidance will have a significant and positive effect on trainees' basic knowledge early in training.

Hypothesis 6: Adaptive guidance will have a significant and positive effect on trainees' strategic knowledge later in training.

Performance is the most salient outcome in training studies. Previous research on advisement using memorization tasks has concentrated almost entirely on this single outcome assessed via declarative knowledge. On complex tasks, training performance can be construed as the application of acquired knowledge and behavioral skills as trainees respond to task situations and demands. The present study focused on two types of performance, basic and strategic.

Basic performance refers to trainees' ability to perform fundamental task operations that must be learned in order for participants to develop more advanced skills. Basic performance requires individuals to draw on their declarative knowledge (e.g., knowledge of facts) and procedural knowledge (e.g., knowledge of rules). Through practice and experience, declarative knowledge begins to be compiled or proceduralized and trainees are able to execute activities quicker and with fewer errors (Anderson, 1982). Strategic performance refers to a trainee's ability to perform more complex and difficult operations that are based on comprehension of deeper task elements. Essentially, strategic performance is a measure of an individual's ability to not only integrate several basic and complex skills but also his or her ability to differentially and selectively apply the resulting constructions to varying task characteristics (Tennyson & Breuer, 1997). Mathieu, Heffner, Goodwin, Salas, and Cannon-Bowers (2000), for example, trained individuals to operate a low-fidelity flight simulator task. During each mission, participants needed to perform a number of basic operations, such as flying and positioning the plane. However, they also needed to develop strategies that would allow them to reach specified waypoints, engage enemy planes, and maximize their survivability. Moreover, participants needed to adapt these strategies as task conditions changed.

Consistent with prior research on advisement, we believe that adaptive guidance will have a positive effect on trainees' performance. Adaptive guidance is designed specifically to achieve this goal.

It provides information to direct trainees' efforts to overcome deficiencies. Adaptive guidance also attempts to increase trainees' on-task cognition and enhance the quality of their self-regulation. As mentioned above, guidance is sequenced so as to focus on basic or fundamental aspects of the task early in training and strategic or complex aspects of the task later in training. Thus, we hypothesize that adaptive guidance will have a positive effect on basic performance early in training, and a positive effect on strategic performance later in training.

Hypothesis 7: Adaptive guidance will have a significant and positive effect on trainees' basic performance early in training.

Hypothesis 8: Adaptive guidance will have a significant and positive effect on trainees' strategic performance later in training.

Our research also examines individuals' basic and strategic performance in a final, more difficult generalization trial. The length of this trial is doubled, the number of targets is increased dramatically, and the rules are modified to increase the complexity and dynamics of the task – all of which require participants to generalize their basic skills and adapt their strategies. We argue that the positive effects of adaptive guidance will transfer to this more difficult generalization trial. Guided individuals should have a more solid foundation of basic skills and a deeper comprehension of how to properly utilize and adapt their task strategies. Thus, we argue that adaptive guidance will have a positive effect on trainees' ability to generalize their basic skills and adapt their strategic skills in the generalization trial.

Hypothesis 9: Adaptive guidance will have a significant and positive effect on trainees' basic and strategic performance during the generalization trial.

Preliminary Model

Due to the limitations inherent in past research on advisement, the primary purpose of this study is to examine the impact of adaptive guidance on several, multifaceted processes and outcomes in a complex training environment. However, it is also important for research in this area to begin to formulate a theoretical framework that depicts in greater detail the means by which advisement and similar training strategies have their effects. Based on the theoretical rationale offered in the hypotheses above, we developed a preliminary model that posits processes by which adaptive guidance exerts its effects on performance and generalization outcomes. This model is presented in Figure 2.

Insert Figure 2 about here

The model has two primary purposes. First, it captures the processes by which adaptive guidance impacts trainees' learning and performance. Second, it incorporates the temporal nature of these processes. A fundamental feature of adaptive guidance is that it sequences individuals' study and practice so that they learn the fundamental or basic aspects of the task before learning the more strategic or complex aspects of the task. In addition, adaptive guidance is designed to build individuals' self-efficacy early in training when they are likely to experience difficulty and errors, and focuses more on sustaining on-task cognition and effort later in the task when individuals are likely to become fatigued or overconfident in their performance. To capture these differential effects across time, the model presented in Figure 2 essentially outlines two paths by which guidance influences learning and performance.

The first path occurs early in training, when adaptive guidance is hypothesized to increase individuals' self-efficacy and direct their self-regulatory focus to studying and practicing fundamental aspects of the task. This should result in increased basic knowledge and performance early in training. As training progresses, adaptive guidance shifts to the second path. During the later stages of training, adaptive guidance attempts to maintain individuals' on-task cognition and shifts their self-regulatory focus to studying and practicing more strategic aspects of the task, which should ultimately lead to increased strategic knowledge and performance. Consistent with the sequenced and developmental nature of adaptive guidance, individuals who exhibit a stronger foundation of basic knowledge and performance early in training should display higher levels of strategic knowledge and performance later in training. Finally, individuals with higher levels of basic and strategic knowledge and performance are expected to demonstrate enhanced transfer of these knowledge and skills to the more complex and demanding generalization trial.

Method

Participants

Participants were 277 undergraduate students enrolled in psychology courses at a large midwestern university, who were given course credit for participating in the study. Fifty-six percent of the participants were female and most (86.3 percent) were between 18 and 21 years old.

Task

This research used a version of TANDEM (Dwyer, Hall, Volpe, Cannon-Bowers, & Salas, 1992), a PC-based radar-tracking simulation. TANDEM presents participants with multiple targets on the computer screen. Trainees were required to learn how to perform a number of both basic and strategic skills. With respect to the basic skills, they needed to learn to "hook" targets on the radar screen, collect cue information, and make 3 subdecisions to classify the target's characteristics. Then they needed to use this information to make an overall decision (take action/clear). Trainees received points for correct decisions and lost points for incorrect decisions. They also needed to learn strategic skills that involved preventing targets from crossing two perimeters located on their display. Individuals needed to learn how to identify the perimeters, determine which targets were higher priority than others, and make trade-offs between targets that were higher or lower priority. Targets that crossed perimeters cost points.

Procedure

Training was conducted in a single three-hour session. During this session, individuals learned to perform the radar simulation described above. Sessions were conducted with groups of one to 12 participants. Trainees were first presented with a brief demonstration of the simulation that outlined its features and decision rules. They were then shown how to use an on-line instruction manual that contained complete information about the simulation. After this brief demonstration, trainees had an opportunity to familiarize themselves with the task in a one-minute trial. They were then told that they would progress through nine study, practice, and feedback cycles, followed by an opportunity to demonstrate how much they had learned on a more difficult and complex version of the task.

Participants were given nine 9-minute training trials to acquire the knowledge and skills needed for the generalization trial. Each training trial consisted of a cycle of study, practice, and performance feedback. They had two-minutes to study the on-line task manual, five minutes of hands-on practice, and two-minutes following practice to review their feedback. Veridical descriptive feedback on all aspects of the task relevant to both basic and strategic performance was provided immediately following the completion of each practice trial. Trainees in both the adaptive guidance and learner control conditions received feedback regarding their performance on the same task dimensions. Following the third and ninth practice trials, participants completed measures of self-efficacy and on-task cognition and were given basic and strategic knowledge tests. They were also given a 5-minute break following the third and ninth trials. After the second 5-minute break, participants were presented with a 10-minute generalization task that was more difficult and complex than the scenarios they had practiced.

Training Manipulations

Learner control condition. Learner control served as the control condition in this experiment. Learner control trainees received descriptive feedback on the same aspects of performance as trainees in the adaptive guidance condition, but did not receive any guidance information. As discussed earlier, individuals can be given control over several different aspects of the learning process, including pace, sequence, and content. In the present study, participants in both conditions were given control over what they could choose to study and practice (content) and the order in which they chose to study and practice the material (sequence). Trainees were also given some control over the pace of their learning, such as being able to exit the computerized manual and feedback early; however, for design reasons it was necessary to impose maximum time limits on the study and practice sessions. At the beginning of the training session, individuals in the learner control condition were given a randomized list of learning topics. They were told that the list outlined all the important aspects of the task they needed to learn and that they may want to focus on these topics during their training, but what they chose to study and practice was at their discretion. In addition, trainees in both conditions had access to the same training materials (e.g., training manual) and all trainees had the same degree of control over the sequence, content, and pace of the learning process. However, because the experimental condition contained the adaptive guidance, only the control condition was a "pure" learner control situation.

Adaptive guidance condition. The initial presentation of adaptive guidance followed the "familiarization" trial and was identical for all participants in this condition. It instructed trainees that they should learn to "hook" targets on the radar screen and then collect information to classify the target's characteristics, and that they should study their manual to help them learn these skills. Following this initial presentation, all subsequent guidance was adaptive based on the trainee's performance during the preceding practice trial and was presented immediately following feedback.

Guidance was adaptive based on three levels of performance. Cutoff scores based on pilot data were set at the 50th and 85th percentiles to allow discrimination among scores representing low, medium, and high performance. These scores make minimum performance quite easy and maximum performance difficult to achieve. It is important to recognize that while these standards determined the form of guidance a trainee received, trainees were not aware of the cutoff scores or percentiles. Based on the standards, adaptive guidance provided evaluative information to help the trainee calibrate current progress, and then suggested actions the trainee could take to improve deficiencies. Advisement was framed in a manner that recommended or suggested certain actions or behaviors the trainee could choose to do, rather than controlling what participants did. Based on previous performance, it suggested skills and strategies they should be practicing to improve on their deficiencies. For example, if a person hadn't learned how to hook targets, the adaptive guidance suggested to the person that this is an area in which he or she needs additional practice and study.

Adaptive guidance for individuals within each of the three ranges of performance on a particular topic was designed as follows. For individuals below the 50th percentile, guidance informed the person that they had not yet learned how to perform the necessary skill or strategy and provided suggestions on what the trainee should be practicing and studying to improve. Guidance for individuals between the 50th and 85th percentile informed the trainee that they had reached a level of minimal performance, but needed to become more proficient. In addition, the guidance suggested what the trainee should be practicing and studying to improve. For individuals above the 85th percentile, guidance informed the person that they had mastered the skill or strategy, and that they should concentrate on improving in areas in which they were still deficient. Thus, based on prior performance, each presentation of adaptive guidance provided participants with evaluative information to help them judge their progress on the task and individualized suggestions regarding what they should study and practice to improve.

In addition to helping trainees identify areas of needed improvement, adaptive guidance was designed to sequence trainee learning and practice. Sequencing is important because it allows trainees to develop fundamental skills before proceeding to the more strategic aspects of the task where the fundamental skills will be required. At the beginning of training, individuals in the guidance condition were given a topic sheet similar to that given to those participants in the learner control condition. The only difference was that for participants in the adaptive guidance condition, the list was ordered in a ramped sequence. In addition, before each block of three training trials, adaptive guidance recommended the topics trainees should be covering during the upcoming practice and study sessions. Then, following each practice session, adaptive guidance gave trainees specific information about what they needed to practice and study to improve their performance in these topic areas.

Measures

Cognitive ability. All participants were administered the Wonderlic Personnel Test at the beginning of the experimental session. The Wonderlic Personnel test is a well-known and widely used index of general cognitive ability suitable for a wide range of jobs and tasks. The user's manual for the Wonderlic (1992) offers predictive validities as high as .63, with reliability estimates from .73 to .95, depending on the type of reliability estimated.

Self-efficacy. Following the third practice trial (time 1) and the ninth practice trial (time 2), self-efficacy was assessed using an 8-item self-report measure developed for use in this research paradigm (Ford, Smith, Weissbein, Gully, & Salas, 1998; Kozlowski, Gully et al., 2001). This measure assesses self-efficacy with a Likert-type scale rather than with ratings of confidence about particular aspects of the task (Hysong & Quinones, 1997; Lee & Bobko, 1994). A sample item is "I am confident that I can cope with this simulation if it becomes more complex." Individuals responded on a 5-point scale ranging from strongly disagree (1) to strongly agree (5). Coefficient alpha for this scale was .91 at time 1 and .94 at time 2.

On-task cognition. Following the third and ninth practice trials, participants completed an 8-item measure of on-task cognition adapted from Kanfer et al. (1994). This measure is designed to measure the frequency of on and off-task thoughts. A sample item is "I paid close attention to the kind of errors I was making." Response options are on a five-point Likert-type scale ranging from "never" (1) to constantly (5). Higher scores on this measure indicate more on-task cognition and greater persistence on the task. Coefficient alpha for the on-task cognition scale was .75 at Time 1 and .81 at Time 2.

Practice Sequence. The sequence of trainees' practice was measured by having trainees complete a self-report measure after each training block which asked them to record the three main concepts or skills they practiced during the preceding three trials. The self-report measures were scored by determining how many of the relevant task skills the trainee practiced during the relevant trial block.[1] A trainee could receive a score ranging from zero to three on each questionnaire depending on how many of the relevant task skills (presented in Figure 1) the trainee indicated practicing during each training block. Practice sequence at time 1 and practice sequence at time 2 were based on what participants practiced during the first three trials and the last three trials, respectively.

Study sequence. The data collected by the on-line instruction manual provided information concerning what each participant studied, and when during the training they studied the material. For each training block, the amount of time a trainee spent studying the relevant pages of the manual was calculated and used to determine the degree to which the trainee was following the appropriate sequence of study (presented in Figure 1). Study sequence at time 1 and study sequence at time 2 were based on what trainees studied during the first three trials and the last three practice trials, respectively.

Knowledge. Following the completion of the third and ninth practice trials, participants completed a basic knowledge test. The basic knowledge test consisted of thirteen multiple-choice items focusing on the extent to which declarative knowledge (e.g., target characteristics; basic operating features of the task) about the task had been acquired. Following the third and ninth practice trials, participants also completed a strategic knowledge test. This test consisted of fourteen multiple-choice items focusing on the extent to which strategic knowledge (e.g., locating the perimeters, identifying high priority targets) about the task had been acquired. A confirmatory factor analysis (CFA) confirmed that these two scales were indeed measuring different aspects of knowledge ($\chi^2(64, N = 277) = 94.25$, $p < .01$; $\chi^2/df = 1.47$; GFI = .95; AGFI = .93; CFI = .94; and RMSEA = .04).

Performance. Data were collected that allowed assessments to be made of participants' performance on both the basic and strategic aspects of the task. Indicators of a participant's basic performance were composed of the number of correct and incorrect decisions. Strategic performance was composed of the number of times participants zoomed out, and the number of markers hooked in an effort to identify the location of an invisible outer perimeter. Strategic performance also included the number of high priority targets that were processed. Time one indicators were based on performance in the third practice trial, and time two indicators were based on performance in the ninth practice trial.

To examine whether the relevant performance indicators could be combined to create separate basic and strategic performance composite variables, we conducted an exploratory principal components factor analysis using varimax rotation. Following the Kaiser normalization criterion guideline of selecting components with eigenvalues greater than one, two components were rotated. The first component consisted of the strategic performance indicators and the second component consisted of the basic performance indicators (Component 1: eigenvalue = 2.10, variance = 42.00%; Component 2: eigenvalue 1.39, variance = 27.73%; all loadings of variables on their respective components were greater than ±.70; all cross-loadings were less than ±.20). The indicators were standardized within time period and summed using unit weights to create separate basic and strategic performance composites.

Generalization performance. The same basic and strategic performance composites were used to assess participant's performance on the final and more difficult generalization trial. Participants performed a final 10-minute trial at the end of the three-hour session. This trial was more difficult, complex, and dynamic than the practice trials. The generalization trial was longer in duration (10 vs. 5 minutes), it included more targets on the screen (60 vs. 22), a greater number of targets popped up suddenly on the screen, and more targets threatened the outer perimeter. In addition, rules were modified so that a greater number of points were deducted when targets crossed the visible inner perimeter (175 points) and the invisible outer perimeter (125). To achieve high levels of basic and strategic performance on this final trial, participants needed to adapt their strategies and generalize their skills.

Data Analytic Strategy

We first performed a repeated measures multivariate analysis of covariance (RM-MANCOVA) to examine the omnibus effect of adaptive guidance over and above ability, and to establish the differential effects of adaptive guidance over time. We then tested each hypothesis using hierarchical regression analyses, controlling for cognitive ability. After testing each of the main effect hypotheses, we used structural equation modeling (Amos 3.6; Arbuckle, 1997) to test the fit of the preliminary model. To simplify presentation of the model, ability is not shown in Figure 2, though it was used as an exogenous covariate to control for its effects on knowledge, performance, self-efficacy, and on-task cognition.

Results

Variable means, standard deviations, and intercorrelations are displayed in Table 2. Our first set of analyses examined the omnibus effects of adaptive guidance and time using a RM-MANCOVA, with cognitive ability as the covariate. The between-subjects effects showed that both cognitive ability, $F(8, 267) = 12.95$, $p < .01$, $\eta^2 = .28$, and adaptive guidance, $F(8, 267) = 24.94$, $p < .01$, $\eta^2 = .43$, had significant and substantial overall effects. These results not only support treating cognitive ability as a covariate in all subsequent analyses but also show that adaptive guidance had a stronger overall effect than cognitive ability on the outcomes examined. Within-subjects effects revealed that time had a significant effect on the outcomes examined, $F(8, 267) = 12.38$, $p < .01$, $\eta^2 = .27$. This is not surprising, since individuals are expected to improve over the course of training. Finally, the analysis also revealed a significant interaction between time and adaptive guidance, $F(8, 267) = 11.65$, $p < .01$, $\eta^2 = .26$, thereby supporting our decision to hypothesize differential effects of adaptive guidance across training. A series of hierarchical regression analyses were conducted to test specific hypotheses.

Insert Table 2 about here

Direct Effects

Process variables. The hierarchical regression results predicting the process variables are presented in Table 3. Hypothesis 1 posited that adaptive guidance would have a significant positive effect on individuals' self-efficacy, especially during early training. As expected, trainees who received adaptive guidance reported significantly higher levels of self-efficacy early in training ($\beta = .12$, $p < .05$). Contrary to expectations, however, trainees who received adaptive guidance also reported significantly lower levels of self-efficacy later in training (β = -.12, $p < .05$). An examination of these results revealed that both groups of trainees increased in self-efficacy across time as would be expected. Adaptive guidance boosted individuals' self-efficacy early and maintained this high level across training trials. Individuals who did not receive guidance had lower self-efficacy early, but they also displayed a greater increase in self-efficacy across time and had higher levels of self-efficacy later in training. One possible explanation for this finding is that by providing evaluative information about performance, adaptive guidance kept trainees from becoming overconfident in their skills and abilities later in training.

Insert Table 3 about here

Hypothesis 2 posited that adaptive guidance would have a significant positive effect on trainees' on-task cognition, especially during the later stages of training. Contrary to expectations, however, adaptive guidance did not have a significant effect on trainees' on-task cognition at either time 1 (β = .04, ns) or time 2 (β = -.01, ns). Hypotheses 3 and 4 predicted that adaptive guidance would lead trainees to follow a more appropriate, ramped study and practice sequence, respectively. Consistent with expectations, adaptive guidance had a significant positive effect on trainees' study sequence early in training (β = .19, $p < .01$) and later in training (β = .48, $p < .01$). Trainees who received adaptive guidance spent over 25% more time studying the relevant training topics relative to learner control trainees. Also consistent with expectations, adaptive guidance had a significant positive effect on trainees' practice sequence both early in training (β = .42, $p < .01$) and later in training (β = .52, $p < .01$). Trainees who received adaptive guidance practiced almost twice as many of the relevant training topics at each time period as learner control trainees. Thus, hypotheses 3 and 4 were supported.

Outcome variables. The hierarchical regression results predicting the outcomes are shown in Table 4. Hypothesis 5 argued that adaptive guidance would have a significant positive effect on trainees' basic knowledge early in training, but not later in training. As can be seen in Table 4, this hypothesis was supported. Adaptive guidance had a significant positive effect on trainees' basic knowledge early in training (β = .15, $p < .01$) but a nonsignificant effect on basic knowledge later in training (β = .02, ns). Hypothesis 6 argued that adaptive guidance would have a significant positive effect on trainees' strategic knowledge later in training, but not early in training. This hypothesis was supported. As expected, adaptive guidance did not significantly influence strategic knowledge early in training (β = -.05, ns), but did have a significant positive effect on trainees' strategic knowledge later in training (β = .33, $p < .01$).

Insert Table 4 about here

Hypothesis 7 posited that adaptive guidance would have a significant positive effect on trainees' basic performance early in training. As shown in Table 4, this hypothesis was supported. Adaptive guidance had a significant positive effect on trainees' basic performance early in training ($\beta = .21$, $p < .01$), but did not have a significant effect on basic performance later in training ($\beta = -.08$, ns). These findings are expected because adaptive guidance focuses on basic aspects of the task early in training but then transitions to more strategic components. Hypothesis 8 argued that adaptive guidance would have a significant effect on trainees' strategic performance later in training, but not early in training. This hypothesis was also supported. Adaptive guidance did not have a significant effect on strategic performance early in training ($\beta = -.02$, ns) but did have a significant positive effect on trainees' strategic performance later in training ($\beta = .34$, $p < .01$). These findings are expected because adaptive guidance does not shift focus to strategic aspects of the task until later in training.

Hypothesis 9 predicted that adaptive guidance would have a significant positive effect on trainees' basic and strategic performance during the generalization trial. This hypothesis was partially supported. Although adaptive guidance did not have a significant effect on basic performance during generalization ($\beta = -.01$, ns), it did have a significant positive effect on trainees' strategic performance during the more difficult and complex transfer trial ($\beta = .30$, $p < .01$).

Preliminary Overall Model

Having supported the majority of our hypotheses, we believed that the preliminary model presented earlier would provide a good examination of the means by which adaptive guidance has its effects. An analysis of the model using Amos 3.6 indicated moderately good fit to the data ($\chi^2(59, N = 277) = 176.84$, $p < .01$; $\chi^2/df = 3.00$; GFI = .92; AGFI = .85; CFI = .89; and RMSEA = .085 (.071, .100)). As can be seen in Figure 3, which presents the standardized parameter estimates, the effects of adaptive guidance early in training are almost entirely as expected. Trainees who received adaptive guidance had higher levels of self-efficacy and were more likely to follow the appropriate study and practice sequence. Individuals who followed the appropriate study sequence, in turn, had higher levels of basic knowledge. In addition, higher levels of basic knowledge and self-efficacy led to higher levels of basic performance. The only process variable that did not have a large impact early in training was practice sequence, most likely because most trainees focus on the salient basic aspects of the task early in training.

Insert Figure 3 about here

The effects of adaptive guidance later in training were also largely as expected. Figure 3 shows that adaptive guidance trainees were more likely to follow the appropriate study and practice sequence, which in turn led to higher levels of strategic knowledge and performance. In addition, there was a significant positive relationship between study and practice sequence, suggesting that individuals who followed the appropriate study sequence were also more likely to follow a ramped practice sequence. The relationship between adaptive guidance and on-task cognition was not supported, though individuals who reported more on-task cognition later in training did exhibit greater strategic performance as expected.

Consistent with the idea of sequencing individuals' learning process, trainees with a stronger foundation of basic skills and knowledge early in training displayed higher levels of strategic skills and knowledge later in training. Finally, with respect to generalization performance, as expected individuals who had higher levels of basic knowledge and performance during training were better equipped to transfer these skills to the more difficult and complex generalization trial. Similarly, individuals who had higher levels of strategic knowledge and performance during training were able to more effectively transfer their strategic skills to the generalization trial. Finally, we thought that individuals who remained focused and intent on the task would also be more likely to display enhanced generalization performance. The results of the model test supported this finding for basic performance during generalization, but not strategic performance.

Discussion

As we begin the 21st century, organizations are under increasing pressures to develop well-trained workforces with cutting-edge skills. Technological advances have not only created jobs that require complex and adaptive skills but also make it possible for organizational members to be geographically distributed. As a result, today's training systems must be extremely flexible, not only in terms of the instruction they provide, but also in terms of how, when, and where this instruction is delivered. To meet these emerging challenges, many organizations have developed advanced computer-based training applications, such as web-based training, simulations, and distance learning. With an appropriate technical infrastructure, these applications have the potential to be widely accessible and can be delivered to anyone at anytime and anywhere. In addition, with an appropriate instructional infrastructure, they can adapt to the needs, learning styles, and progress of different trainees. In essence, these advanced training strategies provide trainees with the opportunity to control many different aspects of their instruction.

Although these technologically advanced training applications provide individuals with an unprecedented degree of control over their instruction, we know relatively little about how best to assist individuals in taking advantage of this control. The goal of the present study, therefore, was to examine the effects of adaptive guidance as a training strategy on multiple learning processes and outcomes. Although we designed adaptive guidance based on the foundation provided by past research on learner control and advisement, we also aimed to address several limitations that have plagued past research in this area. In addition, we presented and tested a conceptual model of adaptive guidance that provides a preliminary examination of the means by which guidance has its effects. In the following section, we provide a brief summary of the key findings of the current study. We then discuss the implications of these findings for research, organizational practice, and training design.

Key Findings

The primary goal of any training program is to increase individuals' knowledge and performance. Although advanced training technologies offer many advantages, such as accessibility, cost effectiveness, and flexibility, it is important to ensure that the instructional integrity of these programs is maintained. Past research suggests that the learner control inherent in these applications is counterproductive in this regard (Brown, 2001). We hypothesized that supplementing learner control with adaptive guidance would help individuals make better learning decisions and, as a result, positively impact their learning and performance. The results of the current study support this contention. Individuals who received adaptive guidance displayed higher levels of basic and strategic knowledge and performance and were also better able to transfer their skills to the more complex generalization trial. These results are not only consistent with past research that has shown that individuals perform better when learner control is supplemented with some form of advisement, but they also suggest that advanced training programs should include information that helps trainees to make effective use of the control they are given over their own learning. Without such information, the benefits offered by web-based training, simulations, multimedia applications, and other similar training mediums may not be fully realized.

Our results indicated that adaptive guidance had substantial effects. How, and through what processes, did it achieve these effects? One of the major goals of adaptive guidance was to direct individuals' learning so that they not only studied and practiced relevant training material, but also did so in an appropriate sequence. The sequence in which individuals proceed through training is critical because learning is a gradual process in which the acquisition of difficult and complex skills and knowledge depends on the degree to which one has previously learned more fundamental or basic skills and knowledge (Gagné, 1985). In the current study, we found that adaptive guidance was extremely effective in sequencing the study and practice of trainees. In addition, the test of the preliminary model revealed, as expected, that the sequence of individuals' study and practice was an important predictor of learning and performance, especially on more complex aspects of the task. Because past research on learner control and advisement has used relatively simple tasks in which there is no logical, hierarchical organization of material, the sequence of individuals' study and practice has never been examined as an important aspect of guided information. The findings of the current study suggest, however, that when dealing with more complex tasks it is important for advanced training technologies to incorporate information that assists trainees in choosing an effective study and practice sequence.

Adaptive guidance was also expected to influence individuals' self-efficacy. Since adaptive guidance provides individuals with information on how to overcome their performance deficiencies, we believed that it would have a positive impact on self-efficacy, especially early in training when trainees are likely to experience many errors and poor performance. Our results indicated that the information provided by adaptive guidance helped build trainees' self-efficacy early in training when performance problems are most likely to occur. In addition, the test of the preliminary model revealed that individuals' self-efficacy was positively related to their basic knowledge and performance early in training. We also found that, relative to the learner control condition, adaptive guidance trainees had a lower rate of increase in self-efficacy, which yielded slightly lower levels of self-efficacy later in training. This may have helped to keep guided trainees from becoming overconfident in their performance. Research has shown that overconfidence is one of the detrimental aspects of learner control that leads to early termination of study and practice (Tennyson et al., 1980). Since past research on learner control and advisement has failed to examine potential mediating process variables, these results provide new insight into the means by which guided information influences individuals' learning and performance.

Practical Implications

Today's advanced technologies hold the potential to revolutionize the field of training. Despite this potential, many new training techniques simply represent a computerized presentation of existing lecture-based training—they are merely used as new delivery media. In addition, without an instructor to monitor performance and provide feedback on trainee progress, these applications provide individuals with a great deal of control over their learning and little or no guidance on how to make effective use of this control. To extent that the current study and other work on learner control and advisement generalizes, this type of instructional design is ill advised. Yet, as organizations continue to recognize the financial and logistical benefits of moving training out of the classroom, a growing number of training programs are being developed that, we would assert, are not likely to take full advantage of the instructional potential inherent in these new delivery media.

Consider Prudential Insurance, who spent $100 million in 1997 to issue laptop computers to 12,000 of its employees and to develop a sophisticated intranet (Kiser, 2001). Soon, employees were using computers to not only respond to customers' e-mail requests for insurance rates but also to participate in state-mandated education needed to keep their insurance licenses up to date and other training designed to educate employees about Prudential products. Although the new system has saved Prudential more than $3 million in training-related expenses, the technology is not yet being fully utilized in terms of its instructional potential. Many of the web-based courses were developed by simply converting the books and white papers used for product training to rather straightforward page-turning, HTML-based courses (Kiser, 2001). In addition, training results are recorded for accreditation and certification purposes, but are not yet used to provide trainees with information needed for making effective learning choices.

Or consider Cooperative Refining LLC, which has created one of the most advanced oil refinery training centers in the country (Jossi, 2000). The refinery used to train employees on actual plant equipment, until someone opened a valve with the mistaken belief that the exercise was a simulation. Today, computerized simulations allow employees to train on the same instrumentation they use in the plant, but in a much safer environment. These simulations allow employees to experience a wide variety of potential situations and enable them to see how their reactions and decisions influence not just a specific process but also the entire workings of the plant. Currently, the simulations are used mostly for training new recruits, because they help them understand the nature of the refinery process after just a few run-throughs (Jossi, 2000). The more advanced potential of the system, however, is not yet utilized.

We believe that both of these organizations, and others that use similar training technologies, could potentially benefit from the application of the principles underlying adaptive guidance presented in Table 1. For example, both Prudential and Cooperative Refining intend to use technology to create training systems that are better suited to handle differences in employees' training needs. To accomplish this, it will be important to utilize the ability of computer technology to evaluate and diagnose trainees' learning and performance in real time. Hands-on skill demonstrations can be used to assess trainees' performance, or quizzes and sample items can be used to track the learning of concepts. Prudential, for example, uses exams in their web-based programs to track employee performance for the purposes of accreditation and certification (Kiser, 2001). For training purposes, however, this information is limited because it often focuses on a single outcome, declarative knowledge, and is not incorporated into the instructional design. Based on the results of the current study, a more effective design may be to use technology to assess multidimensional indicators of training success, including strategy development, problem-solving, and procedural knowledge, compare the information to task standards, and provide trainees with valuable on-line information on how they are progressing through training and where they can most effectively focus their study and practice. In the long run Prudential could create a system that not only delivers individualized training to people with different needs and learning styles, but also tracks employees' job competencies and points them toward training that would be most beneficial for their professional development. Similarly, using the principles of adaptive guidance, Cooperative Refining could create a simulation system that all employees could use to evaluate their knowledge and performance and determine areas in which they needed to improve their performance.

Technology should also be used to provide learner control where it enhances motivation, and limit it where it harms learning. If the sequencing of content is critical to knowledge and skill acquisition, individuals should be guided through a hierarchical presentation of the training materials. At Cooperative Refinery, for example, the simulations are used to teach new recruits the basics of the refinery process and more experienced employees how to handle different crises. This type of basic-to-complex sequencing can be used both at a more macro level across lessons, or at a more micro level within particular content areas. If, however, the material is more basic and possesses no logical sequence, then individuals should be given the freedom to determine the sequence of their learning so that they gain a sense of control over their learning. Technology should also be used to design training that positively impacts important process variables, which are often neglected in training design. For example, training programs could be developed that focus on the fundamental aspects of the task first and then gradually shift to the more complex aspects of the task once a trainee has reached a certain level of proficiency. This type of design could potentially help to build self-efficacy, maintain on-task attention later in training, and keep trainees from becoming bored or frustrated with the training.

Limitations and Future Research

Although adaptive guidance had substantial and widespread effects in the present study, it is important to acknowledge that the degree to which it adapted to the progress and pace of individual trainees was constrained. That is, guidance was designed to be adaptive to three major levels of performance, but did not adapt to more minute performance differences among trainees. In addition, guidance was designed to address sets of topics at certain times and did not focus on participants' weakest areas. The guidance was designed to indicate the areas in which the individual needed the most improvement, but it also provided information on all topics being covered at the time. Finally, to ensure equivalence across participants, it was necessary to place restrictions on the pace at which individuals could move through the material. As a result of these constraints, future research should examine alternative forms of guidance that allow for enhancements in the degree of adaptability to individual trainee progress.

A second issue involves the measure of trainees' on-task cognition. We hypothesized that adaptive guidance would create the perception that the persistence-performance relationship is positive and, therefore, increase individuals' persistence or on-task cognition. Unfortunately, this hypothesis was not supported, although the overall model test did show that on-task cognition predicted performance late in training and during generalization as expected. Due to the fact that the on-task cognition measure we used is subject to potential confounds, such as performance attributions, future research should utilize other measures not possible in the present design—such as physical task withdraw or time on task—in an attempt to better examine the impact of adaptive guidance on individuals' task persistence. Recent research by Brown (2001) found that time on task was an important predictor of knowledge acquired by individuals in a learner controlled, web-based training program. Thus, it is important for future research to examine how adaptive guidance and similar strategies can be used to influence trainees' persistence.

The potential generalizability of the results of the present study should also be noted. Although young adults using computers at work is a large and growing segment of the work population, the use of a student sample and a synthetic task limits somewhat the degree to which the results of the present study can be directly generalized to other instructional paradigms. On the other hand, the foundations of adaptive guidance specified in Table 1 provide a set of design principles that can be used to guide the application of this instructional strategy to other technologies and paradigms. We believe that the results reported here, based on these principles, have good potential to evidence generalizability. However, additional research is clearly needed to extend the results of adaptive guidance to a range of other technologically based training platforms, including other simulations, web-based systems, and CD-ROM programs. It is also important to note that this is one of the first studies to examine the effects of advisement in a complex training situation. The task employed in the current study is significantly more complex and dynamic than those used in past research and total training time in the current research far exceeded that of past studies. Thus, the results of the present study are the best current indication of how guidance can be used to direct the training of individuals on complex, difficult, and dynamic tasks.

Conclusion

This study was designed to examine the effects of adaptive guidance in a complex training environment. It was found that adaptive guidance had pervasive and substantial impacts on self-regulation process indicators and on the sequence of trainees' study and practice. Adaptive guidance also yielded significant improvements in the acquisition of basic knowledge and performance capabilities early in training, significant improvements in the acquisition of strategic knowledge and strategic performance skills later in training, and significant improvements in the capability to retain and adapt skills in a more difficult and complex generalization situation. Combined, the results of the present study suggest not only that adaptive guidance has high potential as an effective training strategy but that it may also be an effective means for guiding individuals through today's technologically advanced training applications. Future research should expand on these findings in an effort to capitalize on the benefits and eliminate the drawbacks of the growing use of technology in training system design.

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Footnotes

[1] The self-report practice measures were scored by both the first author and an assistant. The first author provided the assistant with a written scoring guide, explained the scoring system, and trained the assistant on a random sample of 50 questionnaires. The author and assistant then independently scored each questionnaire. Inter-rater reliability was .96 for the session one practice questionnaire, .99 for the session two practice questionnaire, and .96 for the session three practice questionnaire. Any disagreements in ratings were resolved through discussion.

Table 1

Foundations of Advisement and Adaptive Guidance

Advisement	Adaptive Guidance
Learner Control over Instruction - Sequence - Content - Pace	Learner Control over Instruction - Sequence - Content - Pace
Individualized Prescriptive Information - Recommends examples or instances based on past performance	Individualized Prescriptive Information - Recommends study and practice material based on past performance
Common Foundation	
Extension	
Recommendations are Unidimensional - Cognitive-based. - Focuses on encoding/repetition. - Surface level.	Recommendations are Multidimensional - Cognitive and skill-based. - Focuses on encoding, integration, and strategy development. - Deeper level.
Limited Diagnosticity of Current Progress - Requires trainee inference based on the number of recommended examples or instances. - Limited impact on self-regulation.	Diagnostic of Current Progress - Provides evaluative information to help trainees judge current progress and calibrate deficiencies. - Facilitates self-regulation.
Training Material Unsequenced - Topics do not build on one another. - Sometimes topics are grouped by similarity.	Training Material Sequenced - Similar topics are grouped and content sequenced from basic to strategic (easy-difficult). - Builds self-efficacy early. - Maintains challenges later in training to enhance on-task cognition and sustain useful levels of self-efficacy.

Table 2

Means, Standard Deviations, and Intercorrelations

Variable	M	SD	1	2	3	4	5	6
1. Adaptive Guidance	0.51	0.50	--					
2. Ability	24.73	4.62	.00	--				
3. Self-efficacy (1)	3.51	0.70	.12*	.21**	--			
4. Self-efficacy (2)	3.86	0.73	-.12	.18**	.50**	--		
5. On-task cognition (1)	4.00	0.54	.05	.17**	.34**	.25**	--	
6. On-task cognition (2)	3.98	0.64	-.01	.24**	.24**	.40**	.57**	--
7. Practice Sequence (1)	2.02	1.03	.42**	.08	.01	-.04	.01	.05
8. Practice Sequence (2)	1.15	0.90	.52**	.06	.10	-.05	.09	.13*
9. Study Sequence (1)	4:08	0:48	.19**	-.02	-.04	.02	.04	.04
10. Study Sequence (2)	1:22	1:01	.48**	-.05	.01	-.10	.01	.03
11. Basic Performance (1)	0.00	1.00	.21**	.27**	.40**	.20**	.23**	.13*
12. Basic Performance (2)	0.00	1.00	-.08	.34**	.35**	.54**	.15*	.34**
13. Basic Performance (G)	0.00	1.00	.00	.39**	.31**	.40**	.20**	.34**
14. Strategic Performance (1)	0.00	1.00	-.02	.23**	.08	.16**	.14*	.10
15. Strategic Performance (2)	0.00	1.00	.34**	.31**	.30**	.16**	.26**	.27**
16. Strategic Performance (G)	0.00	1.00	.30**	.28**	.27**	.13*	.23**	.25**
17. Basic Knowledge (1)	8.69	2.40	.16**	.39**	.31**	.15*	.16**	.22**
18. Basic Knowledge (2)	10.84	2.11	.02	.32**	.33**	.29**	.17**	.36**
19. Strategic Knowledge (1)	6.12	2.41	-.05	.27**	.14*	.15*	.17**	.15*
20. Strategic Knowledge (2)	9.07	2.59	.33**	.34**	.30**	.05	.19**	.24**

Note: (1) denotes that the variable was measured at the end of the third trial or time one; (2) denotes the variable was measured at the end of the ninth trial or time two; (G) denotes that the variable was measured during the generalization trial. * Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at 0.01 level (2-tailed).

Table 2 (cont.)

Means, Standard Deviations, and Intercorrelations

Variable	7	8	9	10	11	12	13	14
1. Adaptive Guidance								
2. Ability								
3. Self-efficacy (1)								
4. Self-efficacy (2)								
5. On-task cognition (1)								
6. On-task cognition (2)								
7. Practice Sequence (1)	--							
8. Practice Sequence (2)	.34**	--						
9. Study Sequence (1)	.14*	.09	--					
10. Study Sequence (2)	.15*	.47**	.13*	--				
11. Basic Performance (1)	.08	.12	.13*	.13*	--			
12. Basic Performance (2)	-.01	-.06	.08	-.02	.44**	--		
13. Basic Performance (G)	.04	.05	.03	.05	.44**	.72**	--	
14. Strategic Performance (1)	.00	.06	-.20**	-.10	.01	.13*	.21**	--
15. Strategic Performance (2)	.13*	.34**	-.06	.23**	.32**	.21**	.34**	.28**
16. Strategic Performance (G)	.07	.27**	-.13*	.25**	.32**	.20**	.36**	.29**
17. Basic Knowledge (1)	.15*	.14*	.21**	.06	.45**	.35**	.38**	.06
18. Basic Knowledge (2)	.01	.10	.08	.02	.32**	.56**	.57**	.14*
19. Strategic Knowledge (1)	.02	.08	-.24**	-.11	.17**	.15*	.23**	.24**
20. Strategic Knowledge (2)	.10	.40**	.03	.35**	.31**	.17**	.25**	.16**

Note: (1) denotes that the variable was measured at the end of the third trial or time one; (2) denotes the variable was measured at the end of the ninth trial or time two; (G) denotes that the variable was measured during the generalization trial. * Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at 0.01 level (2-tailed).

Table 2 (cont.)

Means, Standard Deviations, and Intercorrelations

Variable	15	16	17	18	19	20
1. Adaptive Guidance						
2. Ability						
3. Self-efficacy (1)						
4. Self-efficacy (2)						
5. On-task cognition (1)						
6. On-task cognition (2)						
7. Practice Sequence (1)						
8. Practice Sequence (2)						
9. Study Sequence (1)						
10. Study Sequence (2)						
11. Basic Performance (1)						
12. Basic Performance (2)						
13. Basic Performance (G)						
14. Strategic Performance (1)						
15. Strategic Performance (2)	--					
16. Strategic Performance (G)	.75**	--				
17. Basic Knowledge (1)	.35**	.33**	--			
18. Basic Knowledge (2)	.24**	.25**	.47**	--		
19. Strategic Knowledge (1)	.31**	.27**	.25**	.23**	--	
20. Strategic Knowledge (2)	.47**	.52**	.31**	.31**	.36**	--

Note: (1) denotes that the variable was measured at the end of the third trial or time one; (2) denotes the variable was measured at the end of the ninth trial or time two; (G) denotes that the variable was measured during the generalization trial. * Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at 0.01 level (2-tailed).

Table 3

Hierarchical Regression Results: Predicting Process Variables

Predictor/Step	β	R^2	ΔR^2
DV: Self-efficacy (1)			
1. Ability	.21**	.04**	.04**
2. Adaptive Guidance	.12*	.06**	.02*
DV: Self-efficacy (2)			
1. Ability	.18**	.03**	.03**
2. Adaptive Guidance	-.12*	.05**[a]	.01*
DV: On-task cognition (1)			
1. Ability	.17**	.03**	.03**
2. Adaptive Guidance	.04	.03*	.00
DV: On-task cognition (2)			
1. Ability	.24**	.06**	.06**
2. Adaptive Guidance	-.01	.06**	.00
DV: Practice Sequence (1)			
1. Ability	.08	.01	.01
2. Adaptive Guidance	.42**	.18** [a]	.18**
DV: Practice Sequence (2)			
1. Ability	.06	.00	.00
2. Adaptive Guidance	.52**	.27**	.27**
DV: Study Sequence (1)			
1. Ability	-.03	.00	.00
2. Adaptive Guidance	.19**	.04**	.04**
DV: Study Sequence (2)			
1. Ability	-.05	.00	.00
2. Adaptive Guidance	.48**	.23**	.23**

Note: DV = dependent variable. (1) denotes variable measured at time 1. (2) denotes variable measured at time 2. * $p < .05$. ** $p < .01$. [a]R^2 values do not add up because of the rounding of numbers.

Table 4

Hierarchical Regression Results: Predicting Outcome Variables

Predictor/Step	β	R^2	ΔR^2
DV: Basic Knowledge (1)			
1. Ability	.39**	.16**	.16**
2. Adaptive Guidance	.15**	.18**	.02**
DV: Basic Knowledge (2)			
1. Ability	.32**	.10**	.10**
2. Adaptive Guidance	.02	.10**	.00
DV: Strategic Knowledge (1)			
1. Ability	.27**	.07**	.07**
2. Adaptive Guidance	-.05	.08**[a]	.00
DV: Strategic Knowledge (2)			
1. Ability	.34**	.12**	.12**
2. Adaptive Guidance	.33**	.22**[a]	.11**
DV: Basic Performance (1)			
1. Ability	.27**	.07**	.07**
2. Adaptive Guidance	.21**	.12**[a]	.04**
DV: Basic Performance (2)			
1. Ability	.34**	.12**	.12**
2. Adaptive Guidance	-.08	.12**[a]	.01
DV: Basic Performance (G)			
1. Ability	.39**	.15**	.15**
2. Adaptive Guidance	-.01	.15**	.00
DV: Strategic Performance (1)			
1. Ability	.23**	.05**	.05**
2. Adaptive Guidance	-.02	.05**	.00
DV: Strategic Performance (2)			
1. Ability	.31**	.10**	.10**
2. Adaptive Guidance	.34**	.21**[a]	.12**
DV: Strategic Performance (G)			
1. Ability	.28**	.08**	.08**
2. Adaptive Guidance	.30**	.17**	.09**

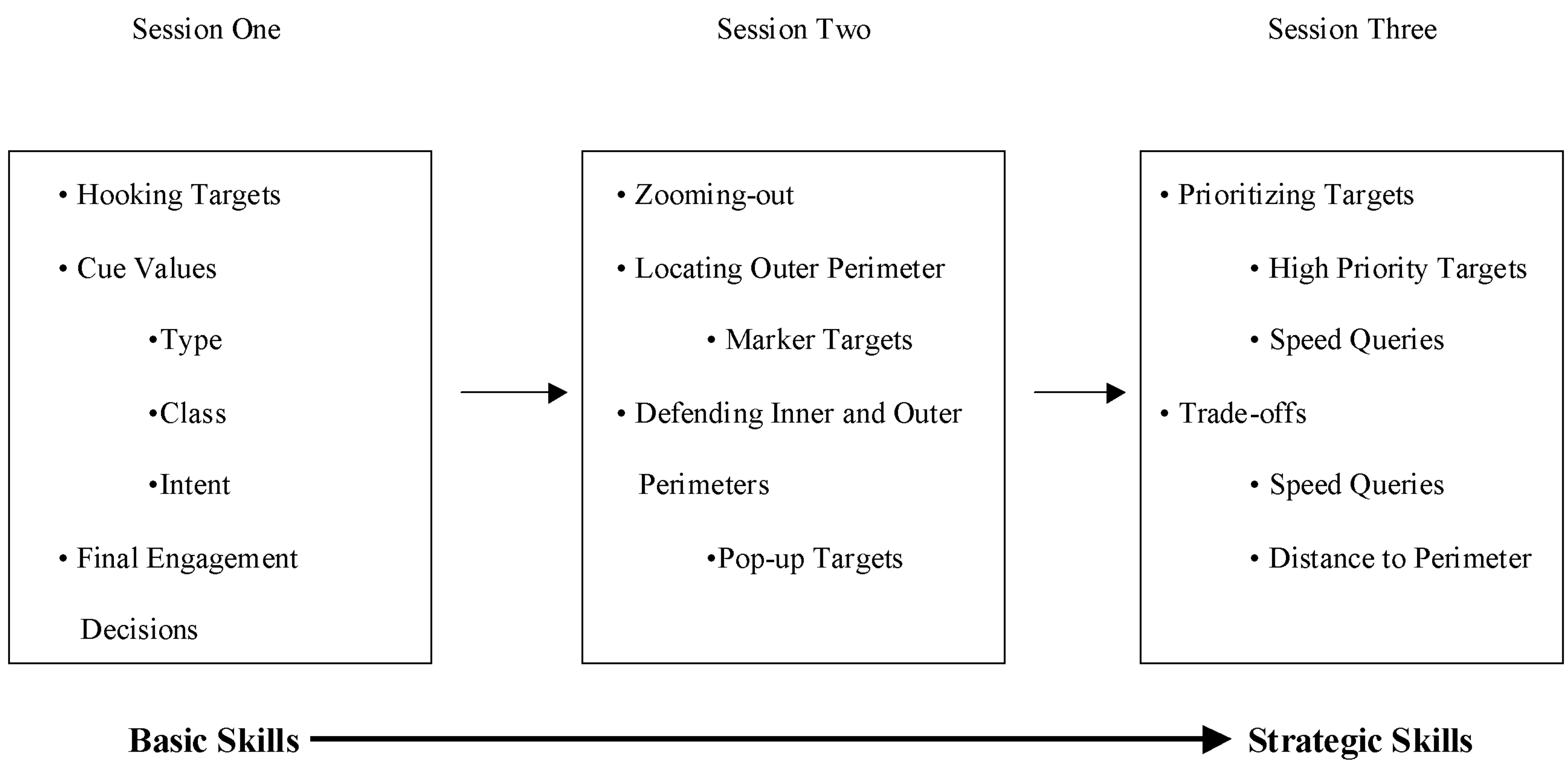
Note: DV = dependent variable. (1) denotes variable measured at time 1. (2) denotes variable measured at time 2. (G) denotes variable measured during generalization trial. * $p < .05$. ** $p < .01$. [a]R^2 values do not add up because of the rounding of numbers.

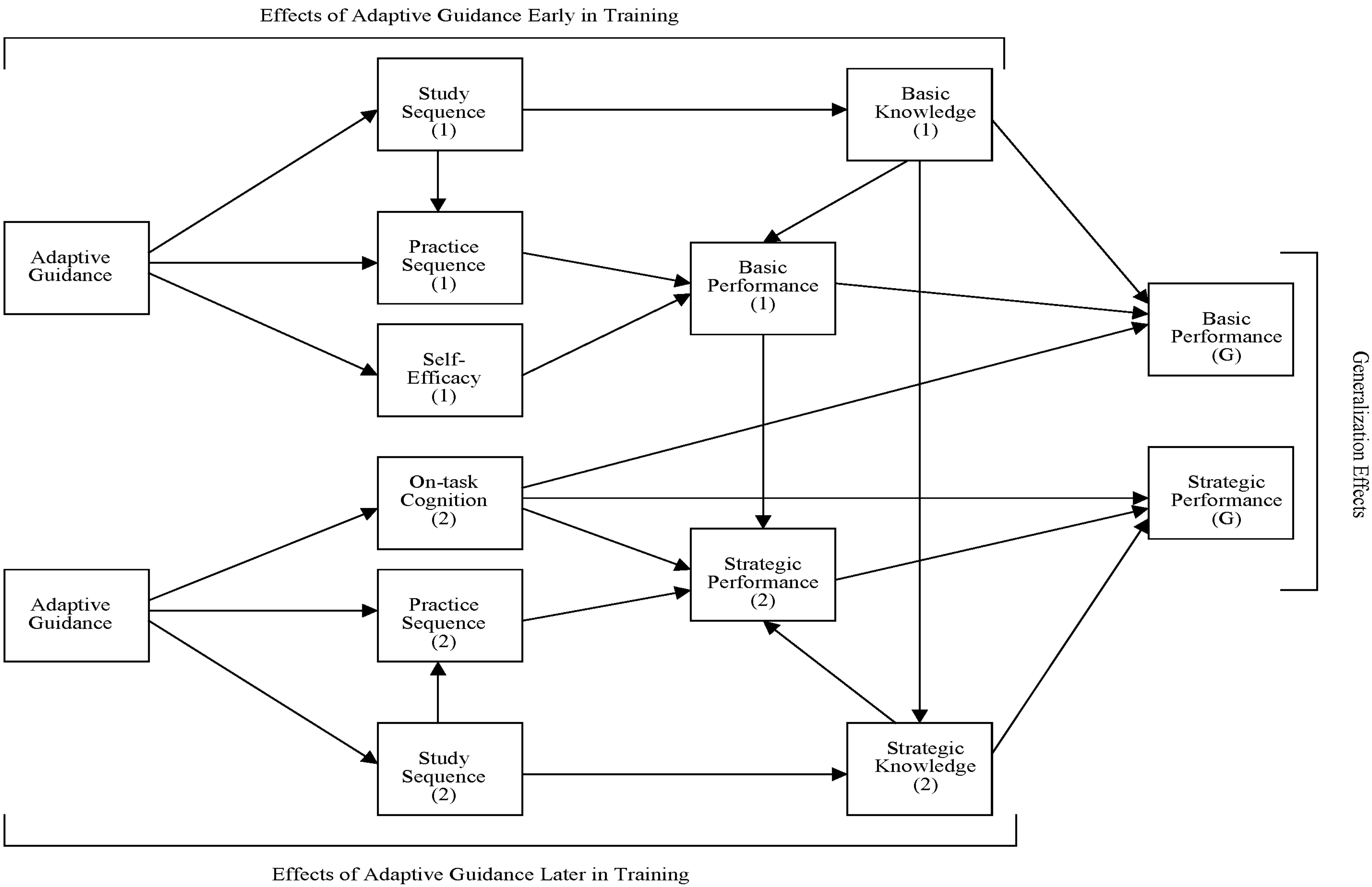
Figure Captions

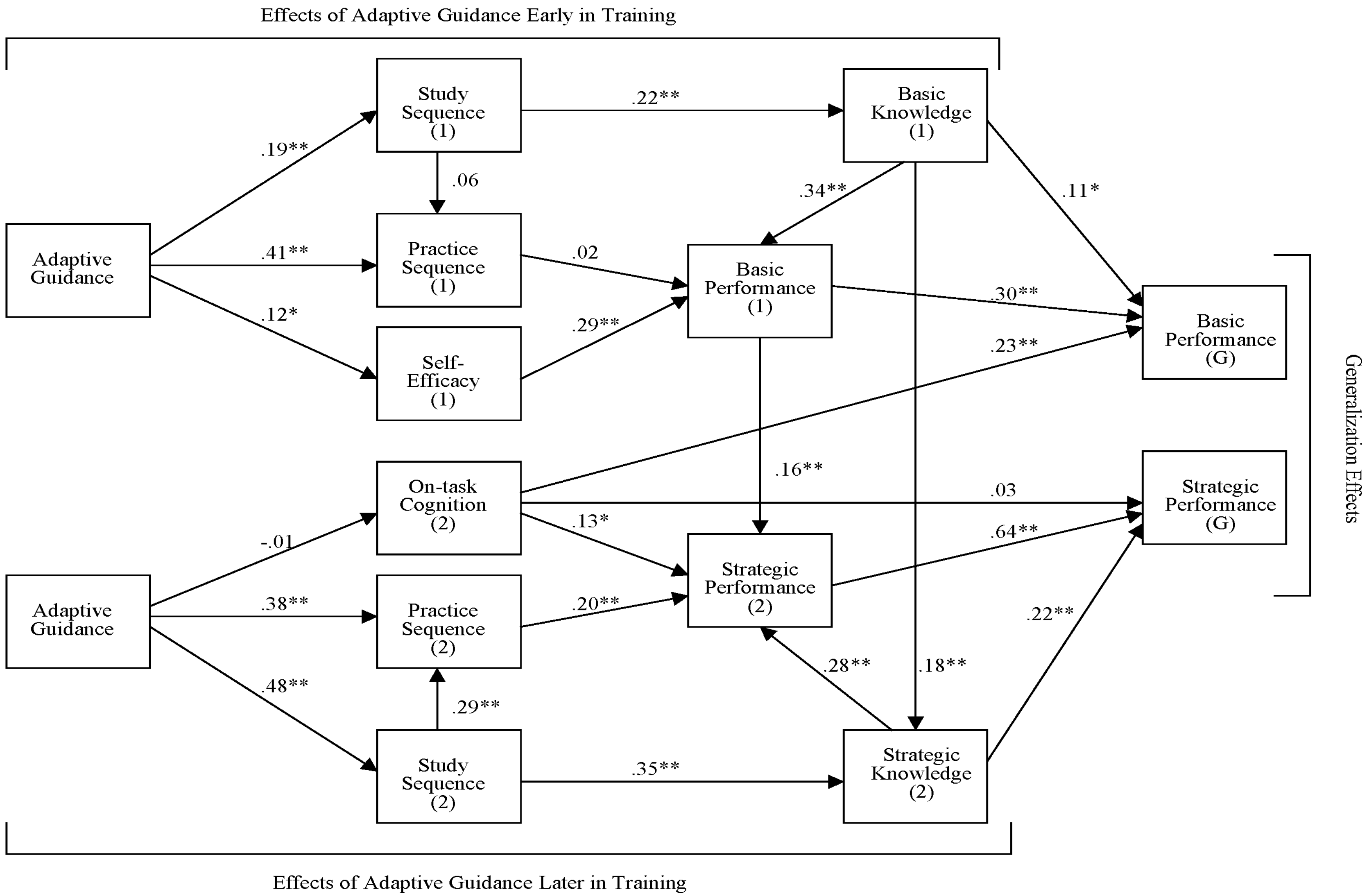
Figure 1. Appropriate ramped sequence of trainees' study and practice.

Figure 2. Preliminary overall model of adaptive guidance.

Figure 3. Summary of standardized parameter estimates among variables. To simply presentation of the model, ability is not explicitly modeled although it served as an exogenous covariate. * $p < .05$. ** $p < .01$.


Session One
Session Two
Session Three
• Hooking Targets
• Cue Values
•Type
•Class
•Intent
• Final Engagement Decisions
• Zooming-out
• Locating Outer Perimeter
• Marker Targets
• Defending Inner and Outer Perimeters
•Pop-up Targets
• Prioritizing Targets
• High Priority Targets
• Speed Queries
• Trade-offs
• Speed Queries
• Distance to Perimeter
Basic Skills
Strategic Skills


Effects of Adaptive Guidance Early in Training
Adaptive Guidance
Study Sequence (1)
Practice Sequence (1)
Self-Efficacy (1)
Basic Knowledge (1)
Basic Performance (1)
Basic Performance (G)
Strategic Performance (G)
Generalization Effects
Adaptive Guidance
On-task Cognition (2)
Practice Sequence (2)
Study Sequence (2)
Strategic Performance (2)
Strategic Knowledge (2)
Effects of Adaptive Guidance Later in Training


Effects of Adaptive Guidance Early in Training
Adaptive Guidance
Study Sequence (1)
Practice Sequence (1)
Self-Efficacy (1)
Basic Knowledge (1)
Basic Performance (1)
Basic Performance (G)
Strategic Performance (G)
Generalization Effects
Adaptive Guidance
On-task Cognition (2)
Practice Sequence (2)
Study Sequence (2)
Strategic Performance (2)
Strategic Knowledge (2)
.19**
.41**
.12*
.06
.22**
.02
.29**
.34**
.11*
.30**
.23**
.16**
.03
.13*
.64**
-.01
.38**
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.20**
.29**
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.22**
Effects of Adaptive Guidance Later in Training