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# THE EFFECTS OF GOAL TYPE AND METACOGNITIVE TRAINING ON COMPLEX SKILL ACQUISITION: IMPLICATIONS OF THE LIMITED RESOURCES MODEL

By

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ABSTRACT

THE EFFECTS OF GOAL TYPE AND METACOGNITIVE TRAINING ON COMPLEX SKILL ACQUISITION: IMPLICATIONS OF THE LIMITED RESOURCES MODEL

By

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Research on the limited resource model of complex skill acquisition has suggested that goals early in skill acquisition may be detrimental to learning and performance because the resultant self-regulation competes for cognitive resources. However, past research has examined primarily performance goals. This study examines whether learning goals sequenced in accordance with hierarchical sequencing theory and/or metacognitive training allow learners be more efficient with their cognitive resources leading to increased learning, and better performance. A conceptual model is offered to examine the impact of goal type and metacognitive training on learning and performance, mediated by metacognitive and learning activity. The model is tested with a 2 (sequenced subgoals) x 2 (presence or absence of metacognitive training) design, analyzed using hierarchical regression. The manipulations were generally unsuccessful at increasing metacognition or learning activity, nor did they increase learning or performance substantially. Metacognitive ratings were the most promising way to measure metacognition. Ability and goal committment, led to knowledge aquisition which predicted performance. Metacognition related to knowledge acquisition. Implications and future directions are discussed.

For my Sister, Sarah.

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# INTRODUCTION

Skilled behavior is essential to virtually all jobs, from typist to truck driver, x-ray reading to radar operation. Training for most jobs therefore necessarily involves some degree of skill acquisition. Although skill acquisition has been systematically studied since the late 1800s, until the 1970s this research was generally conducted on simple, well defined tasks concentrating on issues such as practice, feedback, and interference effects (Baldwin & Ford, 1988). With the increased prominence of cognitive psychology, which places more focus on human learning processes, came new interest and new theories regarding the learning of skilled behavior -- particularly the acquisition of more complex skills than had previously been studied.

This interest in complex skill acquisition parallels changes in the workplace. Great demands for effective skill training are imposed by increasingly complex jobs, increasingly sophisticated technology, and the acknowledgment in business that training is an important way for organizations to gain a competitive edge (Goldstein & Gilliam, 1990; Proctor & Dutta, 1995; Rosow & Zager, 1988). Organizations and researchers are searching for ways to increase the efficiency of training, allowing employees to learn skills better and faster, in order to reduce training time, lost work time, and training costs.

To this end, the cognitive psychology literature has produced theories and programs which advance our understanding of the processes involved in skill acquisition (c.f. Anderson, 1987; Gagne & Glaser, 1987; Kanfer & Ackerman, 1989). Much of the recent attention in the I/O literature has been on the limited resource model of skill acquisition. This model has advantages over other skill acquisition theories because it integrates many important factors from the I/O literature such as abilities, and motivation with newer concepts from the cognitive literature such as cognitive resources and resource allocation.

The purpose of the present study is to examine and build upon the implications of the limited resource model. It is suggested that although research on the limited resource model provides useful insight regarding factors that can inhibit the acquisition of a complex skill, it is limited regarding how much help it provides to those wishing to enhance skill acquisition. The educational and instructional design literatures, however, have identified factors that enhance learning. The proposed study focuses on two potential interventions for the design and implementation of training: 1) the sequencing of training through subgoals; and 2) enhancing metacognitive skills. It is expected that these interventions help the learner focus their resources on activities that maximize learning, and to make the best use of their available resources. A conceptual model is proposed and hypotheses generated to clarify the relationships between metacognition, learning goals, and performance attained by the end of training.

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## Traditional Approaches to Skill Acquisition

Starting with Ebbinghaus's (1885) early work on learning nonsense syllables, the traditional approaches to skill acquisition have been to examine training design factors which affect the learning, retention, and transfer of acquired skills. Training design research has involved altering training conditions to examine the effects of applying such learning principles as identical elements, general principles, stimulus variability, and various conditions of practice.

As Baldwin and Ford (1988) note in their review, the application of these principles has been found to increase trainee performance at the end of training for some skills. Maintaining identical stimulus-response elements has been found to increase performance on both verbal and motor skills (Gagne, Baker, & Foster, 1950; Thorndike & Woodworth, 1901; Underwood, 1953). Teaching general rules and theoretical principles underlying the skills being acquired has been shown to increase performance on skills such as underwater shooting and card sorting (Crannell, 1956; Hendrickson & Schroeder, 1941; McGehee & Thayer, 1961). The inclusion of several training stimuli to increase the trainee's understanding of concepts and their applicability in multiple situations has been found to increase performance on such skills as lever movement and distinguishing spatial arrangements (Adams, 1957; Duncan, 1958). Finally, many different conditions of practice have been studied as training design factors. For example the distribution of practice, whole or part practice, overlearning, and the provision of feedback have each received attention in ri

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the literature. Naylor and Briggs (1962) and Briggs and Naylor (1963) provided evidence that skills learned with distributed practice rather than practice massed at one time are generally learned better and retained longer. Research also suggests that training a skill whole rather than in parts yields better performance if the skill is high in organization but low in complexity (Briggs & Waters, 1958; Briggs & Naylor, 1962). Teaching a skill past the point of successful performance, or overlearning, also has been found to increase performance on skills such as pairing words, operating a control panel, operating hand switches to stimuli, and assembly of a machine gun (Atwater, 1953; Gagne & Foster, 1949; Mandler, 1954; Schendel & Hagman, 1982). Feedback, or providing information to trainees regarding their results, has also been demonstrated as important to learning skills (Macpherson, Dees, & Grindley, 1948; Thorndike, 1927; Trowbridge & Carson, 1932), and that specificity and timing are critical in determining its effects (e.g. Wexley & Thornton, 1972).

In addition to the research on training design factors there has also been, more recently, research to examine trainee characteristics affecting skill acquisition. This research generally involves pretesting the trainees to determine if the speed or success of skill acquisition correlates with the characteristic of interest. The trainee characteristics traditionally studied were abilities. Training samples as ability measures have demonstrated moderate predictive value, for example Downs (1970) found a training sample significantly related to instructor scores for training on sewing machine skills. Aptitude test batteries and ability tests have also predicted skill acquisition to a moderate degree for record keeping skills (Taylor & Tajen, 1948) and s

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supervisory skills (Neel & Dunn, 1960). Overall, however, the use of ability variables to predict trainability has had only moderate success (Baldwin & Ford, 1988; Ghiselli, 1966).

The traditional research focusing on training design characteristics and abilities, while useful, is also limited in scope. In the traditional approaches the trainee is treated as bringing his or her abilities to training to be acted upon by training designs. The success of these designs was primarily measured by success on a test of task performance, or by reducing the training time to successful performance. This approach resulted in a stimulus-response orientation to training design possibilities rather than a series of interventions based upon an understanding of the learner and the learning processes, and the resultant learning outcomes. Perhaps due to the influence of behaviorism, the learning and knowledge acquisition processes remained largely unexplained. For example, while it had long been observed that for many skills performance progresses from slow and error-prone to rapid and accurate (i.e. since Bryan and Harter, 1897), the traditional approaches offered no theories as to how or why performance changes in this manner, and thus what interventions were appropriate for different phases of learning. The learners' thoughts and mental processes went, for the most part, ignored or unexplained. The general learning principles were disconnected since no theory of the human learning processes involved in skill acquisition guided their development. Better models or frameworks were needed that would look at the skill acquisition process itself, the mental processes involved in this learning, and the resulting outcomes of knowledge acquisition processes beyond the typical better performance or faster acquisition. Comprehension of the critical psychological factors in the skill acquisition process was needed both to make better use of the existing principles, and to improve our understanding of how to structure the learning environment and prepare learners for skill acquisition.

Cognitive psychology has emerged to a large extent due to dissatisfaction with behaviorists' stimulus-response approach because the S-R approach did not reveal exactly what a person does with information that is presented in a stimulus. Cognitive psychology takes an information processing approach in order to better understand the processes and outcomes associated with acquiring knowledge (Reed, 1988). In effect, filling in the black box between the stimulus and response -- or, the training design and resulting performance. Cognitive psychologists have tended to use stage theories to examine the processes involved in moving from the laborious error-prone performance of the novice to the smooth, accurate performance characterizing experts at a skill.

One influential framework for understanding skill acquisition and the different nature of performance as it progresses was proposed by Fitts (1964; Fitts & Posner, 1967) who suggested that different cognitive processes are operating during different stages of learning. He thus identified three phases of skill acquisition: the cognitive phase, the associative phase, and the autonomous phase. The cognitive phase as the name suggests, draws heavily upon the cognitive processes of the learner as he or she is attempting to understand the nature of the task and how it should be performed. The cognitive processes taking place during this phase include attending to outside c

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cues, instructions, and feedback. Because of the heavy cognitive activity, performance is slow and contains errors. Once the task instructions are learned and expectations understood, the associative phase begins. During this phase, the learner links or associates inputs more closely with actions. Verbal mediation decreases, there is less interference from outside demands, and attentional requirements decrease. During this phase, error rates and performance times are reduced. Finally, when the autonomous phase is reached, performance is said to be automatic, no longer requiring conscious control.

Anderson (1982; 1987) built upon Fitts's work in developing a theory of skill acquisition that considers the specific processes and mechanisms underlying performance at each phase of skill acquisition, as well as between phases (Proctor & Dutta, 1995). At the beginning of skill acquisition, a learner has little or no domain specific knowledge. Therefore, all knowledge acquired in Anderson's Adaptive Control of Thought (ACT) model starts out in a declarative form, that is, knowledge of facts and information. Declarative knowledge is often referred to as "knowledge of what". Declarative knowledge can be encodings of examples of instructions, encodings of general properties of objects, or other basic information gained through experience, reading text, studying examples, or instruction. To this declarative knowledge, weak problem-solving methods are applied. Weak methods are general problem solving heuristics which can apply to a variety of domains. Examples of weak methods given by Anderson (1987) include means-ends analysis, working backwards, hill climbing, and pure forward search. The weak methods help the learner to take initial steps in solving the problem, but performance is awkward and error-prone. To advance, knowledge must move from declarative to procedural. Procedural knowledge is based on productions, which are essentially if-then condition action rules. Knowledge compilation is the crucial process through which knowledge moves from the declarative to procedural form, producing a domain specific skill. Compilation is comprised of two essential processes: 1) proceduralization, in which necessary declarative knowledge is built into new domain specific productions; and, 2) composition, in which several sequenced rules are collapsed into a single rule which does the work of the sequence. As compilation takes place, and production rules are created and collapsed, there is less need to keep declarative information in working memory since the information is built into productions. Performance becomes smoother, faster, and errors are reduced. Two factors, strength and working memory limitations, determine the success of production execution. Strength determines how rapidly a production applies, and accumulates when the production is applied successfully. It is production strengthening that predicts the typical power-function rate of progress in skill acquisition. Working memory limitations refer to the idea that even perfect production sequences can fail if critical information is lost due to the limited capacity of working memory causing the wrong production be used. However, Anderson (1987) notes that working memory capacity increases with expertise in a domain. Finally, with continued compilation, strengthening, and increased working memory capacity a skill reaches automaticity, in which the skill no longer requires conscious attention, and other tasks can be carried out simultaneously without decreased performance.

Based on Anderson's work, the process of skill acquisition can be defined as the process of moving from declarative knowledge to procedural knowledge and finally to automaticity. That is, acquiring a skill is acquiring facts and information and then compiling this information to an if-then rule based form, and finally strengthening rules until automaticity in which no conscious effort is needed to perform. The use of this definition, and the work of Fitts and Anderson, clearly demonstrates skill acquisition as a process that researchers are now seriously trying to understand from a cognitive perspective. Researchers have identified a number of factors which, from the cognitive perspective, may influence the skill acquisition process. The following section will examine the research on some of these factors.

## Cognitive Factors Influencing Skill Acquisition

### Cognitive Resources.

One of the main factors influencing skill acquisition identified by cognitive psychologists is cognitive resources. Cognitive resources are mental capacities such as attention, (Kahneman, 1973; Kanfer and Ackerman, 1989), processing effort (Norman & Bobrow, 1975) or various forms of memory (e.g. working memory, Stankov, 1983) which can be allocated to tasks in order to bring about performance. As indicated earlier, Fitts and his associates noticed that as one acquired skills, the instructions and expectations become encoded and no longer require as much attention. The differential allocation of cognitive resources in terms of direction and amount of attention, therefore, became an important area of research on skill acquisition. This is especially true as theories of attention themselves evolved.

Kahneman (1973) was an important contributor to cognitive resource theory. Prior to Kahneman's (1973) limited capacity theories, most of the research that had been conducted on attention had been focused on the bottleneck models which postulated that information processing capacity is limited at a certain point in the processing, a bottleneck of sorts. Unfortunately, various authors (among them Broadbent, Treisman, Deutch and Deutch, and Norman) and their research results disagreed as to the location of such a bottleneck. With his limited capacity model, Kahneman was able to shift interest from the bottleneck theories to the capacity demands of tasks. Capacity theories assume that there is a limit on human capacity to perform mental work, and this capacity is allocated with considerable freedom (Kahneman, 1973). According to Kahneman's model, a number of possible activities receive information input and we select which activities to pursue by adding mental resources in the form of mental effort, or attention to this input. Different tasks require different amounts of attention, simple tasks need little, difficult tasks require more. When the supply of attention does not meet demands, performance falters, or fails. In effect, Kahneman states "we merely decide what aims we wish to achieve. The activities in which we then engage determine the effort we exert" (p. 14). According to the model, an allocation policy is responsible for dividing up the pool of attentional effort resources among the various demands. An "evaluation of demands on capacity" acts as a feedback mechanism to the allocation policy and arousal/capacity level. "Interference between tasks is due to the insufficient response of the system to demands, and to the narrowing of attention when effort is high" (p. 16). This model demonstrates both the intensive and selective nature of attention in that it shows both amount and allocation of effort. It is capacity that dictates whether or not tasks can be performed in parallel without detriment to either. This view, that human attention exists as a common "pool" that is divided among tasks which themselves have differential requirements for successful performance is directly reflected in current skill acquisition models.

Norman and Bobrow (1975) modeled the normative effort-performance relationship in skill acquisition implied by Kahneman developing their Performance-Resource Function (PRF). Norman and Bobrow introduce two important categories of tasks: resource-limited and data-limited. When increasing the resources devoted to a task will yield improved performance the task is said to be resource limited. Decreases in resources (say, from dividing resources between tasks) need not cause failure, simply decreased performance.

Whenever performance is independent of processing resources, the task is data-limited. Some tasks are so simple that the processing performance is limited by the simplicity of the data structure. By way of example, Norman and Bobrow consider a person attempting to hear the piano in a room full of other noise; once all that can be done to filter out background sounds has been attempted, performance is based strictly on the quality of the data. Increased allocation of resources can have no further effect on performance, thus the task is data-limited. Norman and Bobrow indicate that most tasks will be resource limited up until the point where all the processing that can be done has been done, and data limited from that point on. From these concepts, Norman and Bobrow constructed a function relating performance to resource allocation placing resources along the x-axis, and performance along the y-axis. The function is a monotonically non-decreasing function; generally difficult task functions are thought of as s-shaped. Moving along the x-axis, initially there is little improvement due to insufficient resources, but as the resources surpass the threshold needed to promote minimal learning and performance, the function becomes steeper, leveling off at the upper limit of processing. At the point where the function reaches an asymptote in performance, the task is data-limited. Learning is demonstrated by faster steeper climbs to the asymptote, leading to successively more concave curves. That is, less and less resources are required for maximum performance as one learns. The PRF is quite consistent with Fitts's model, corresponding with the decrease in required resources as learners encode the instructions and expectations as they move through the cognitive and associative phases to the autonomous phase. Less attention is required for better performance .

Cognitive Abilities.

Researchers of skill acquisition have also continued to investigate the relationships between abilities and performance. Research has demonstrated that cognitive abilities play an important role early in the skill acquisition process, with other abilities (perceptual and motor) becoming more important later in skill acquisition. Woodrow (1938) was among the first to examine the whether or not abilities changed over the course of skill acquisition. Using factor analysis Woodrow noticed that correlations of performance with intelligence tests decreased as skill acquisition progressed. Fleishman and his associates continued this research years later (Fleishman & Hempel, 1954; 1955). Fleishman and Hempel (1954) gave subjects a reference battery of ability tests and then trained them on a factorially complex motor criterion task. Criterion scores and task scores were intercorrelated and factor analyzed. The results showed that several cognitive variables were important early in skill acquisition, but later in acquisition motor factors and task specific factors dominated. The authors found that their results generalized to a discrimination and reaction time test (Fleishman & Hempel, 1955) with cognitive abilities like spatial relations and verbal factors accounting for variance early in acquisition, and motor abilities like reaction time and rate of movement accounting for variance late in acquisition.

This work has been carried further and applied to cognitive tasks in recent research by Ackerman. The beginnings of his current model date back to earlier versions Ackerman (1986; 1987). In this work, Ackerman brings several of the theories regarding cognitive factors affecting skill acquisition together. Particularly, Ackerman integrates work from Norman and Bobrow's (1975) theory regarding the PRF, and Shiffrin and Schneider's (1977) controlled vs. automatic processing distinctions.

At first novel or difficult tasks are what Norman and Bobrow call resource-limited, more resource yield better performance. However, as Shiffrin and Schneider demonstrated, tasks are inconsistent no automatic processing will evolve even with considerable practice and performance will remain resource-dependent. On the other hand, if a task has the consistent characteristics necessary to support the development of automatic processing, the task will become less resource-dependent and more data-limited. As a task becomes totally automatic then fast effortless performance is a possibility.

Ackerman maps his fusing of the PRF to controlled-automatic processing onto the abilities debate, noting that Kahneman's (1973) theory of undifferentiated structure of attention is roughly equatable with Spearman's general intelligence factor. Ackerman (1986; 1987) develops three important principles: 1) individual differences in broad general ability are equatable with individual differences in amount or efficiency of attentional resources; 2) the transition from controlled to automatic processing is equatable with resource-dependent to resource-insensitive performance characteristics; and 3) the ability determinants of performance are associated with the extent and type of resources required by the task. These principles lead to a model of skill acquisition which reflects Fleishman and Hempel's (1954; 1955) findings that cognitive abilities dominate early in skill acquisition and psychomotor abilities dominate later. In Ackerman's model, initial performance on any task is highly resource-dependent and thus performance is determined by g, and general content abilities (spatial, verbal, etc.). For tasks with inconsistent characteristics, general and content abilities continue to be the key to performance throughout as the task remains resource-limited. However, as consistent tasks become data-limited, automatic processing develops and only the specific skills/processes that overlap automatic processing become predominant factors for performance; the task becomes ability insensitive from the standpoint of g and content abilities. Ackerman (1986; 1987) tested this model, measuring various types of mental abilities including g, content abilities like spatial and verbal, as well as abilities believed to determine performance later in the task when it is resource insensitive such as psychomotor and perceptual speed. Ackerman assessed skill development on both verbal and spatial tasks with consistent and inconsistent mapping similar to those used by Schnieder and Shiffrin (1977). Ackerman correlated performance with the various abilities and the resulting performance-ability functions were equatable with the PRF, and consistent with his theory. Overall, the fit of the PRF to the progression of abilities seemed promising though in need of refinement.

This refinement occurred in Ackerman (1988) in which the model is altered in two ways. First, its structure is adapted to make it radex-based and hierarchical in nature. Second, Ackermans's (1988) model is integrated with the three phases of skill acquisition suggested by Fitts and Posner (1967) and Anderson (1982; 1987). On top of the model is g (general cognitive ability). Just below g are the broad content abilities (figural, numerical, and verbal -- which is most important depends on the content of the task). General cognitive ability and the content abilities are said to be important for the first stages of skill acquisition -- procedural knowledge. As one begins the second stage of skill acquisition, knowledge compilation, perceptual speed becomes more important to performance. Finally as the third phase of procedural knowledge begins and automatization occurs, psychomotor ability emerges as the predominant determinant of performance.

Ackerman (1988) presents eight experimental manipulations beginning with reaction time (RT) choice discrimination tasks like those used in previous skill acquisition study, but ending with a more complex air traffic controller task. The experiments manipulated the relevant task variables such as consistency and complexity and examined correlations with perceptual speed and general ability through skill development. Further work on a task with more inconsistent components was also performed in Ackerman (1992). The results of these experiments clearly indicated overall support for the model. For consistent tasks g and content abilities are the major determinant of performance early, but as acquisition progresses perceptual speed and then psychomotor ability become more important. For inconsistent tasks, g and general content abilities are strong and consistent determinants of performance.

Motivation.

In addition to resources and abilities, psychologists have also studied how personal cognitions influence the acquisition of skills. Much of the work in this area involves cognitions pertaining to motivation before and during skill acquisition. Two of the most thoroughly studied of these variables are self-efficacy and self-regulation.

Self efficacy. Self-efficacy has been defined as an individual's belief in his or her capability to perform a specific task, or task specific confidence (Bandura, 1982). Individuals obtain information with which to make an efficacy judgment is a number a ways, such as performance accomplishments, vicariously through observation, persuasion, and physiological indexes (Schunk, 1989). Information gathered from these sources is weighed and combined in a cognitive appraisal taking into account the person and situational factors to make an efficacy judgment (e.g. perceived ability, task difficulty, amount of effort expenditure, assistance received, patterns of success or failure, or perceived similarity to models). Bandura (1982) hypothesized that perceived self-efficacy affects motivation by affecting one's choice of activities, effort expenditure, and persistence.

Although early self-efficacy research by Bandura and his associates was in a therapeutic context (training people to cope with feared situations), self-efficacy has been examined as important to learning skilled behavior. At the start of a learning activity, learners may differ in their perceptions of their capabilities to acquire knowledge, perform skills, master the material, and so forth. This affects the effort they extend and ultimately skilled performance. Schunk (1981; 1982) taught a cognitive skill to low achieving children either via a model or through step by step instructional pages. Half of the subjects were given effort feedback to enhance self-efficacy (they were told they solved problems because they worked hard, or got them wrong because they did not put forth enough effort). However, this effort feedback did not always seem to have the intended effects. While telling subjects that the reason for their success is effort did support self-efficacy, telling them they did not work hard enough when they got a problem wrong created the impression that they were failing, and thus that they were not capable. These effects were disentangled in Schunk (1982) where the hypothesized relation between self-efficacy and performance was examined by deriving the probability of performance as a function of efficacy. Schunk found that regardless of the treatment, higher efficacy was found to be associated with progressively greater skill. Path analysis indicated direct paths from self-efficacy to skill and persistence.

In fact, self-efficacy has been found to predict performance in a number of different cognitive tasks, such as learning from print (Salomon, 1984), writing (Meier, McCarthy, & Schmeck, 1984), and learning mathematics skills (Relich, Debus, & Walker, 1986). However, it is not just for cognitive tasks that self-efficacy is found to influence performance, motor skills are also influenced by self-efficacy. Feltz (1982) found that self-efficacy and prior performance predicted subjects' ability to learn a back dive, and that past performance affected self-efficacy which impacted future performance. Barling and Abel (1983) found a positive relationship between self-efficacy and aspects of tennis performance. Similarly, McAuley (1985) found evidence for a positive relationship between efficacy and performance in gymnastics. Eyring, Johnson, and Francis (1993) found that cognitive ability, task familiarity, and self-efficacy predicted individuals learning rates on the Air Traffic Control (ATC) task, and only self-efficacy predicted asymptotic (final) performance. Finally, Bandura and Cervone (1983) found that self-efficacy is important for goal attainment. These researchers tested subjects given improvement goals, feedback, or both in an ergometer task. Only the goals + feedback condition was effective in increasing effort. In the goals + feedback condition, perceived self-efficacy for goal attainment significantly predicted subsequent effort among the subjects.

Clearly, self-efficacy has substantial motivational impact on learning and performance on a variety of different skill types through its effects on the effort that is put forth by the learner.

Self Regulation. Self-regulatory processes are related to self-efficacy processes. Self-regulation ought to affect skill acquisition by aiding people to reach their goals. According to Karoly (1993) self-regulation refers to those processes that enable an individual to guide his or her goal directed behavior over time and across contexts. Regulation implies thought, affect, behavior, or attention via the use of specific mechanisms and supportive metaskills. Locke et al. (1981) proposed that goals influence behavior by directing attention, mobilizing on-task effort, encouraging task persistence, and facilitating strategy development. However, most of the research on goal setting has focused around issues of how various aspects of the goal impact performance. Difficult, specific goals have been demonstrated to be effective on all but very complex tasks. Self-regulation theories of motivation focus more precisely on how goals help the individual to mobilize effort, maintain persistence, and direct attention. According to Kanfer (1992), self-regulation theories generally come from three perspectives: social learning, cybernetic control, and resource allocation.

Social learning theories view goals as giving the individual a cognitive representation of desired outcomes (Bandura, 1986). Self-regulation toward these goals involves self-observation, self-evaluation, and self-reaction (Bandura, 1982; F. Kanfer, 1970). Self-observation refers to directing attention toward one's own behavior. Self-evaluation involves comparing this behavior to the goal. Whereas, self-reactions are affective reactions and efficacy outcomes for future goals. If the self-evaluation reveals that the individual is far from reaching their goal, this may result in a self-reaction of dissatisfaction and, assuming the person feels they are capable of reaching the goal, increased effort. If the person feels they are not capable of reaching the goal (low self-efficacy), then the discrepancy between current state and goal state may have no impact.

Cybernetic control theories of self-regulation date back to Carver and Scheir (1981) building upon the work of Powers (1973). Their theory is based on the negative feedback loop and a hierarchical goal structure. In control theories, the goal is compared to the current state and when there is a discrepancy, cognitive and behavioral output are enacted toward reducing the discrepancy. When there is difficulty reducing the discrepancy, then attention drops to a lower order goal in the hierarchy. When this lower goal is reached, then attention can shift back to the higher order goal.

Finally , resource allocation theory of self-regulation posited by Naylor and Ilgen (1984) is a cognitive framework attempting to explain choices among acts as competing options for resource allocation. The individual attempts to maximize their anticipated influence under a set of constraints. Motivation is viewed as involving expected utility considerations in that the individual weighs their affect against self perceptions of the behavior-outcome contingencies. This theory holds that there are three basic contingency relationships in motivation: commitment to the act is related to the product produced by the act (A-P), the product of the act is related to the evaluation of the product by and observer (P-E), and the evaluation of the product is related to outcomes resulting from the evaluation (E-O). Setting a goal for someone in terms of output thus affects their P-E relationship. The goal in effect changes the zero point (minimally acceptable output for a neutral evaluation) of the P-E relationship thus changing the balance of the other relationships. This theory offers an explanation for why overly difficult or non-specific goals may lower performance by altering the perceived utility of various allocations of effort.

In sum, the research on the cognitive variables that influence skill acquisition yielded some progress, but this progress been made in different directions. Some research has progressed our understanding and theorizing about resource allocation, other research focused on the changing nature of abilities during skill acquisition, and still other research addressed motivational directions involving how and why we expend effort. Thus, each of the models could explain some aspects of skill acquisition, but the influences of abilities and the influence of motivational processes remained separate. Both the abilities research and the motivation research dealt to some extent with the nature of cognitive resources and how they are applied, but a theory was needed to bring the two together. In effect, to combine the research on abilities with the research on motivation as they reflected the newer cognitive concepts of skill acquisition. Such a model was set forth in a monograph by Kanfer and Ackerman (1989).

In their monograph, the authors pose the limited resources model of skill acquisition, an integrative aptitude by treatment interaction model for the ways in which ability and motivation affect performance. The authors posit attention as a core construct, citing Norman and Bobrow's resource-limited/data-limited distinction and PRF. In addition, they draw on Anderson's (1982) skill acquisition model. Kanfer and Ackerman note that as learners move from declarative knowledge to procedural knowledge and automaticity, performance requires less attention and thus the task moves from resource-limited to data-limited. The processing of declarative data is resource-dependent early in skill acquisition since great demands are placed on cognitive resources. As the learner progresses through compilation and proceduralization, however, the skill becomes automatized and less resources are required freeing resources for other activities. As with earlier Ackerman research, the abilities crucial to performance are posited to be general cognitive ability and broad content abilities early in skill acquisition, but progress to perceptual and psychomotor ability as the skill is proceduralized. In Kanfer and Ackerman (1989), there is an equating of general ability with cognitive resources such that those with more general cognitive ability are viewed as having more resources to devote to the task at the start.

The major contribution of this limited resources model of skill acquisition to the literature involves the inclusion of motivational components in the model which are quintessentially the allocation policies proposed by Kahneman's "evaluations of demands on capacity". Motivational processes in the Kanfer and Ackerman model are separated into distal motivational processes and proximal motivational processes. Distal processes involve the choice to engage some or all of one's resources for attainment of a goal and involve three utility relations espoused in Kanfer (1987). Like the Naylor and Ilgen model, resource allocation decisions are made based upon perceptions of utility contingencies. In the limited resources model, there are three fundamental relationships: effort to performance (E-P), performance to utility (P-U), and effort to utility (E-U). Resource allocation is a main determinant of the effort to performance relation. Norman and Bobrow's PRF is essentially an E-P relationship based upon task characteristics. However, the E-P relations are viewed as having only indirect influence on performance through their function of linking utilities to goals and actions. Distal motivation processes are antecedent to task engagement, and do not draw resources from the learning task. When goals involve complex or novel skills, goal attainment necessitates sustained attentional effort in order to overcome difficulties and requires "iterative, proximal motivational activities" to sustain the attentional effort (Kanfer & Ackerman, 1989, p.661).

Proximal motivational activities are responsible for the distribution of attentional effort to on and off task activities while performing the task. According to the limited resources model, the proximal motivational activities together comprise self-regulation. These activities differ from distal processes because: 1) they are enacted while engaged in the task; and 2) require the devotion of critical attentional resources, potentially taking resources away from task performance. When there are little slack resources (i.e. periods of high engagement) the result may be attenuated performance. It should be noted that the function of self-regulation in the limited resources model is to detect changes in the performance-resource function as skills are automatized and allow for the reallocation of the resources as necessary. If the results of this reallocation are beneficial to goal attainment, then the additional resources can ultimately outweigh the costs causing an increase in performance.

Self-regulation in the Kanfer and Ackerman model reflects Social Learning models described earlier in that self-regulation is comprised of three activities: self-monitoring, self-evaluation, and self-reaction. Self-monitoring refers to the focusing of attention on specific aspects of performance or behavior, and the consequences of the behavior. Self-monitoring is not necessarily accurate, and errors in judgement about one's capabilities can lead to insufficient allocations of attention, and thus, insufficient performance. Self-evaluation, the authors note briefly, is the comparison between desired goal state, and current performance. The size and direction of any discrepancy is postulated to interact with self-reactions to influence later decisions about allocation of resources.

Finally, self-reactions can be of two types in the model. The first type is affective called self-satisfaction and the second involves perceptions of task-specific capability or self-efficacy. One's self-satisfaction and self-efficacy can be positively or negatively influenced depending on the size and direction of the discrepancy between current and desired state examined in self-evaluation.

Self-reaction, and its interaction with self-evaluation, have important implications for the application of resources, and for the importance of goals. Because tasks require less resources as they are proceduralized, goals keep people motivated by setting difficult performance standards against which to self-evaluate yielding more dis-satisfaction (due to a presumably larger gap between desired state and current state). As long as there is sufficient efficacy, the results are continued self-regulation and resources application. When goals are reached, self-satisfaction occurs, and self-regulatory processes stop.

Kanfer and Ackerman posit an interaction between goal (motivation) and ability such that those of high ability can make use of goals earlier, but those of low ability benefit more from using goals. Initially on a novel complex task, learners must use all of their resources to learn the task. Self-regulation early is postulated to take away from the resources devoted to learning which attenuates performance. Because high ability people have more resources to apply, they will learn faster and more quickly reach a point at which they have sufficient resources free for self-regulation. Low ability people, however, will benefit more from a properly applied goal, since they start lower and have more room for improvement.

Three experiments were conducted to test the model using the complex Air Traffic Control (ATC) task. Results indicated that goal setting did not improve performance when goals were set early in skill acquisition. The pattern of correlations for abilities was as they predicted. The expected interaction between ability and goal intervention was found such that those with higher ability benefitted earlier from having a goal. Declarative training lowered initial cognitive load allowing goal setting to be effective earlier, but procedural training did not allow the goal setting intervention to be effective earlier. Low ability people in the declarative training group benefitted the most over time.

## Limitations Of the Skill Acquisition Literature.

The skill acquisition theory and research to date, exemplified by Kanfer and Ackerman's (1989) limited resources model, has led to a deeper understanding of the cognitive processes involved in skill acquisition. A number of important findings have emerged. One finding is that limitations on human cognitive resources play an important part in skill acquisition. The research has demonstrated that early in skill acquisition of a complex novel task with consistent elements, the learner is taxed in that he or she must attempt to apply limited resources to learning the declarative knowledge. These processes of encoding the instructions, expectations, and task information are resource intensive, and preclude the learner from successfully performing other activities, like self-regulation, without attenuating the performance of both. The fact that humans are limited in resource capacity, and that people differ in the amount of resources they have to apply can account for why it takes longer to acquire difficult tasks, why people cannot perform multiple novel tasks with success, and to some extent why people differ in the speed with which they acquire tasks.

A second important finding is that tasks are not equally resource consumptive throughout acquisition. Virtually all current theory recognizes this fact, most clearly modeled by the PRF (Norman & Bobrow, 1975). As a novel task is compiled, the declarative information becomes linked to task behavior decreasing the need to keep this knowledge active in memory. With practice the production rules develop, and the task becomes less resource dependent until automaticity in which the task become data-limited. Kanfer and Ackerman (1989) demonstrated that subjects performing their ATC task were not able to regulate to performance goals early in skill acquisition and that attempts to do so actually were detrimental to performance. However, when comparable goals were provided after declarative knowledge was learned, enough resources had been freed to make self-regulation possible without taking resources from learning. The end result was that performance increased. Thus, in planning a useful intervention there is a need to consider where and how resources are being used.

A third important finding from the more recent skill acquisition work makes it clear that self-regulatory processes play an important role in the acquisition of a complex skill. Since the task itself essentially determines how much resources are required for learning, the onus is on the learner to make sure that sufficient resources are devoted to the task to fulfill these requirements. Insufficient resources may lead to detriments to learning and performance. How well a person is able to determine the task resource demands and allocate the appropriate resources will impact their performance when acquiring difficult tasks which require iterative allocations of attention. This is true particularly if learning different task elements requires different quantities of resources.

While the skill acquisition research has identified cognitive resources and regulation as important variables in the processes of skill acquisition, there are several limitations from a training perspective. The first problem is that this research is descriptive, not prescriptive. Simply put, the research tells us what occurs during learning, but has not yet indicated interventions trainers may use to help learners to acquire skills. In fact, the Kanfer and Ackerman (1989) work demonstrates what **not** to do -- give learners performance goals early in training. What interventions trainers can use to aid learners in making use of their resources remains to be clarified and demonstrated by systematic research.

A second shortcoming in this research is a limited view of performance. When a person is acquiring a skill, they are essentially balancing between *learning* the skill and *performing* the skill. The two are not necessarily mutually beneficial. Sometimes learning involves exploration, making mistakes on purpose, or other behaviors that will not lead to good performance. From a training point of view, learning itself is a type of "performance" in the acquisition of a skill. Therefore, it is wholly appropriate to set goals not simply in terms of performance in the outcome sense (i.e. number of planes landed, points scored etc.), but also in terms of learning. This is particularly true early in skill acquisition while the person is devoting the majority of cognitive resources to the encoding of declarative knowledge, and compiling this information to productions. Kanfer and Ackerman, however, only gave their subjects outcome performance goals, causing them to split resources between learning the task, performing, and self-regulating. This is well demonstrated in the third study in Kanfer and Ackerman (1989). Expecting high performance early in the skill acquisition process is fairly unrealistic to most training situations. In training, learning is the short term goal, and is expected to result in high performance in the long run. Thus, a failure to recognize learning as a form of performance during skill acquisition and consequently the use of only outcome-based performance goals is a second problem with the skill acquisition literature to date.

A third problem with is the failure to examine *how* the devotion of resources to a problem produces better performance. The limited resources model, like other models, stops at the distinction between "on-task resources" and "off task-resources". To simply say that more on-task resources will be added and performance will therefore improve is incomplete. These resources need to be devoted to some activities which result in learning, performance, or self-regulation. Similarly, the limited resources model do not cover strategy evaluation as part of self-regulatory behavior. This neglects what is actually done with the resources devoted to the task. As it is with politicians, the models seem to suggest that simply throwing resources at a problem is enough to solve it. Of course, the way in which these resources are used, the activities and strategies in which the learner engages, produce more or less learning and performance. So, we must make an effort to understand what "on-task" activities are during skill acquisition, and to determine how resources are allocated on the task, and impact skill acquisition.

<u>A Training Perspective</u>

From a training perspective, a central issue is how the limited resource model can be used to help improve skill acquisition. Research in this area is decidedly lacking. The limited resource model is an integrative attempt to understand the processes of skill acquisition. The model is meant to bring together various theories of skill acquisition, and to clarify the cognitive processes involved. However, while there has been substantial support for this model or its components (Ackerman, 1988; Ackerman, 1992; Kanfer & Ackerman, 1989; Kanfer et al., 1994) the implications of this model for training have not been identified and tested. While the current research is informative regarding what not to do (i.e. set performance goals early in acquisition), extensions to what *should* be done to improve skill acquisition are needed. Identifying and testing the types of interventions that have implications for the use of the learner's cognitive resources is therefore an important next step toward increasing the efficacy of the limited resource perspective of skill acquisition.

Two such interventions have been chosen for examination in the current study. The first intervention is the sequencing of instruction by setting systematically sequenced subgoals. The second intervention is metacognitive training prior to skill acquisition. These interventions were chosen because they met three essential criteria: 1) there are solid theoretical reasons grounded in the limited resources model of skill acquisition to expect these interventions to enable learners to improve skill acquisition by making better use of their resources; 2) these interventions have been found to be effective in other literatures (i.e. the instructional design and educational literature);

and 3) these interventions are ones that trainers can tailor to virtually any skill training. While there are undoubtedly other interventions meeting these criteria, the aforementioned interventions appear to be at least a logical initial effort to build upon the limited resource model.

Using Subgoals to Sequence Learning.

The skill acquisition literature has ignored the sequence of training as having impact on learning. The skill acquisition literature suggests that for tasks with consistent elements, skill acquisition progresses through stages (Anderson, 1982; Anderson, 1987; Fitts & Posner, 1963). Therefore the sequence in which one learns, and the goals relevant to this learning, ought to be arranged accordingly. One way which has been found effective to direct learning is the use of goals, or more specifically subgoals, to direct the learner. Locke, et al. (1981) in their review state that goals operate, in part, by mobilizing and directing effort. People behave in a way consistent with a goal to which they are committed. For this reason, learning subgoals are an effective way for trainers to direct the learner and sequence their training. Rothkopf and Billington (1979) demonstrated that learning goals served effectively to direct effort. Likewise, Hofmann (1993) suggests that learning goals help the learner to avoid detrimental cognitive interference, such as that which occurs when the learner is faced with numerous competing demands. Thus, learning goals are a useful way to help learners to sequence their learning.

From a limited resources perspective, there are clear indications that subgoals must be chosen carefully. As mentioned, Kanfer and Ackerman (1989) set performance subgoals early and found them to be detrimental to learning and performance. This demonstrates that just having subgoals will not necessarily be beneficial, it is important to choose these goals so that they are consistent with what we know about the process of learning and skill acquisition. The subgoals must be in an order that allows the attainment of earlier subgoals to free up resources for later subgoals. The subgoals should thus be based upon learning theory, not chosen at random.

The Instructional Design literature explicitly addresses issues of instructional sequencing. There are, in fact, several instructional sequencing theories (e.g. Skinner, 1953; Issuable, 1960; Gagne, et al., 1992; Reigeluth & Stein, 1983). The one chosen for guidance here is Gagne's hierarchical sequencing theory. This theory was chosen because: a) it is one of the most well known sequencing theories; b) this theory can assist in the choice of logical subgoals, and c) Gagne's theory can explain why knowledge gained in earlier subgoals aids in the learning from later subgoals.

Gagne, et al. (1992) posit five types of learning outcomes: verbal information, intellectual skills, cognitive strategies, motor skills, and attitudes. Verbal information is simply what we commonly refer to as declarative knowledge of facts and information. Intellectual skills are the "how to" types of knowledge associated with what has been called procedural knowledge. Cognitive strategies govern one's own learning, remembering, and thinking; they have been referred to as self-regulation and self-monitoring, and include comprehension monitoring and other metacognitive activities. Motor skills are learned capabilities that underlie performances whose outcomes are reflec

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reflected in the speed, accuracy, smoothness, or force of bodily movement. The performance of motor skills embodies intellectual skills in the guiding procedures and executive subroutines . Finally, attitudes are affective, persisting states that modify the individual's choices of action. A positive attitude toward something means a person will tend to do that thing more often. As this paper is focusing on cognitive variables, attitudes as affective components will not be a main concern. Likewise, since motor behavior embodies intellectual skills, consistent with previous discussion, the focus is on the intellectual skills responsible for complex motor behavior.

Gagne and his colleagues believe that goals in learning exist in a hierarchy with lower goals containing the prerequisites to the accomplishment of later goals. Gagne and Merrill (1990) suggest that learner needs to acquire a goal schema early on in the learning process. Gagne, et al. (1992) write that "the schema relates the goal to its prerequisites, that is, to the kinds of skills and knowledge that the learner must retrieve and use when engaged in the enterprise" (p. 180). The lower order goals in this hierarchy are referred to as "enabling objectives" and are either essential or supportive prerequisites for specific performance objectives. Gagne et al. (1992) write "the learning of intellectual skills is most clearly influenced by the retrieval of other intellectual skills that are prerequisite. Usually these are simpler skills and concepts that, when analyzed, are revealed to be components of the skill to be newly learned (R.M.Gagne, 1985). Results of analysis of this sort may be expressed as a learning hierarchy" (p. 111). Gagne and his colleagues state that for intellectual skills, the most direct effect of prior learning is through the retrieval of other intellectual skills and informatio

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information which are prerequisite components of the current learning. This notion of hierarchical goals has more recently been adopted by authors more familiar to the I/O literature, most notably by control theorists such as Carver and Scheir (1981) as well as Lord and Levy (1994). White (1974) also argues that the retrieval of prerequisite skills has direct supporting effect on learning the targeted intellectual skill. Therefore, it is important to make sure that the lower portions of the learning hierarchy are attained first to support and enable the learning of the higher order skills.

Gagne proposes that learners start with verbal information and simple intellectual skills, and precede to more complex intellectual skills. Verbal or declarative information is considered to be such things as labels, facts, ground rules, and bodies of knowledge. The prerequisites to verbal information learning include meaningfully organized sets of information, language skills, cognitive strategies, and attitudes. Simultaneous to the learning of verbal information, some lower order intellectual skills are also learned. These include discrimination, concrete concepts, and defined concepts. Discrimination involves being able to tell different objects apart. Concrete concepts involves being able to identify the properties of objects. And, defined concepts is being able to produce the meaning of a class of objects, events, or relationships. Once these lower order intellectual skills are attained, the learner can begin to do more complex higher order learning such as rule development. Rules are the knowledge of how to respond with a class of relationships among classes of objects and events. Rules are important because they give regularity to performance over a variety of situations. Finally, as the learner develops these rules, he or she can move

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move on to the most complex skills: higher order rules and problem solving. Higher order rules are complex combinations of simpler rules which can be invented for the purpose of solving practical problems. Problem solving is the development of these higher order rules without guidance. Higher order rules should exhibit transfer of learning across situations. The prerequisites to the development of rules, higher order rules and problem solving are the simpler skills and verbal information found in the lower part of the hierarchy.

Gagne and his colleagues bring this learning hierarchy, attention, and goals together at the point of instruction. Gagne et al. (1992) write that before presentation of the stimulus material, three things must take place: a) gaining the learners attention, b) informing the learner of an objective or goal, and c) stimulating the recall of prerequisite learning. This is in line with the earlier stated propose of subgoals: the focusing and maintenance of attention. Gagne's point of view reinforces the need to take the learners attention and focus it, by stating the objective. This helps to learners direct cognitive resources and to define what "on task" (to use the Kanfer and Ackerman term) activity ought to be for this part of the learning task. Then, there is the need to stimulate the recall of prerequisites to aid in learning, this will be most important when there has been time elapsed between learning lower order skills and the learning of higher order skills. When they are learned without time lag then the prerequisites ought to be readily available. Gagne's notion of hierarchical sequencing of learning goals can thus be understood as important to making the best use of cognitive resources. Using subgoals to gain and focus attention to systematically master the verbal information and lower order skill so that the later learning of rules and higher order rules is possible will bring about better performance and learning by the end of the training.

There is some empirical support to back this intuitive notion that prerequisite information and skills are required for an end performance goal to be effective. Earley and Lituchy (1991) tested goal setting models and found one practical implication of their work was that for goal setting to be successful, there is the need to ensure that the employees have the requisites to perform. This speaks directly to the performance goals set by Kanfer and Ackerman (1989). Setting end performance or ultimate goals early on ignores the sequencing need to develop prerequisites first. Earley, Lee, and Hanson (1990) found that for complex tasks and jobs, there is a lag between the time new employees receive a goal and the time when the employee has enough skill to perform and translate the goal into action. People who lacked full understanding tended to switch strategies too often, never allowing any strategy they tried to take hold. They obviously lacked the knowledge needed to evaluate their strategies accurately. This finding is consistent with a similar finding by Dachler and Mobley (1973).

Not only should later learning be enhanced by earlier work, but if resources can be sufficiently focused on a small but meaningful portion of the task, enough resources should be available such that self-regulation is possible without being detrimental to performance. Bandura and Schunk (1981) found that subgoals allowed for better and faster learning, higher self-efficacy due to subgoal success, and more accurate self-assessment than a more "distal" goal. Schunk (1984) found better performance and self-efficacy using subgoals, especially with a reward for goal attainment. Stock and Cervone (1990) found that subgoals lead to self-efficacy in line with subgoal attainment (positive or negative self-efficacy depended upon whether or not the subjects achieved the subgoals), and the learner had more information about their progress on the task. Therefore, it is quite reasonable to expect learning subgoals to increase the learning of the individual, the ultimate performance of the individual, the use of learning behaviors by the individual, and the self-regulation of the individual relative to the learning goals.

Metacognition.

A second intervention that should have a beneficial effect on the use of resources during skill acquisition, and thus on learning and performance, is metacognitive training. Metacognition is defined as knowledge of, and control over, cognition (Flavell, 1979). Metacognitive knowledge is considered the knowledge of one's own thoughts, memories and capabilities. Flavell (1987) separated metacognitive knowledge into knowledge of person variables, task variables, and strategy variables. Person variables involve knowledge about intraindividual and interindividual differences in cognitive propensities, capabilities, and aptitudes. For example, the knowledge that one's own math skills are better than one's verbal skills, or that one's verbal skills are better than someone else's would be intra- and interindividual metacognitive knowledge respectively. In addition, Flavell discusses universal metacognitive knowledge. This is knowledge of what is true for all people. For examp

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example, the knowledge that human short term memory capacity is seven plus or minus two units. Metacognitive task knowledge is the knowledge about the demands and constraints of different tasks and information encountered. Examples of common metacognitive task knowledge we acquire are such things as the knowledge that densely packed or technical information is more difficult to process than other types of material (like fiction); or that it is easier to get the gist of a story then memorize it verbatim . Through experience people learn about the demands of different types of tasks, and must take these demands into account in order to achieve their goals. Finally, knowledge of metacognitive strategy is the knowledge of techniques for monitoring and controlling cognition. Metacognitive strategy can be distinguished from cognitive strategy in that a cognitive strategy is enacted to get one to a cognitive goal or subgoal, whereas a metacognitive strategy is to monitor and direct the cognitive progress to make sure the goal is well met. For instance, to get the sum of a column of numbers the obvious cognitive strategy is to add them. A metacognitive strategy might be to add the numbers a second time or even a third to make sure the goal has in fact been met correctly. Adding is a cognitive strategy, but re-adding to double check is a metacognitive strategy.

The counterpart to metacognitive knowledge is metacognitive control or executive control (Kluwe, 1987). Metacognitive control includes such behaviors as classification, checking, evaluation, and anticipation. Classification, elsewhere called monitoring, provides information about the status, type, or mode of cognitive activity and answers the question "What am I doing here?". Checking provides information about the state of the cognitive system and activity in order to answer the question "How am I doing?" relative to a desired state which will result in metacognitive knowledge. This is equivalent to Kanfer and Ackerman's self-evaluation, except that it is specific to the evaluation of cognitive activity as opposed to motor activity or performance. An example is the assessment a person might make that they are not thinking clearly because they are tired. Evaluation, is similar to checking, but Kluwe asserts that it goes beyond checking in providing information about the quality of cognitive activity because criteria are actually applied in evaluation. For example, a person might say "my plan is no good because it fails to rule out any risks." In addition to these activities, Kluwe posits that people undertake the regulation of processing capacity. People must decide to what to devote resources, and how much of their capacity to devote. In order to make good use of one's cognitive capabilities, resources must be focused on task relevant information with enough resources to successfully complete the task.

Research on metacognition indicates that people differ as to their metacognitive skills and capabilities, and that these differences are not simply a refection of differences in cognitive ability (August, Flavell, & Clift, 1984; Swanson, 1990). Expert-novice research suggests that experts have better domain specific metacognitive skills than novices. Not only do experts have more or better strategic knowledge, they are better able to evaluate their strategies. Etelapelto (1993) found experienced computer programmers to have better metacognitive knowledge of strategies, better metacognitive control, and better metacognitive on-line awareness than novices.

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Etalapelto found that expert programers were more able to identify a good or ideal strategy for comprehending a program than novices, and experts identifying an ideal strategy are more likely to use this strategy than are novices suggesting an ideal. In addition, experts were more aware of which strategies they were using, in that their reported strategies were more likely to match their the actual strategies used. Research shows that relative to novices, experts are more likely to discontinue unsuccessful problem-solving strategies (Larkin, 1983) and are more accurate in judging problem difficulty (Chi, Glaser, & Rees, 1982). Good readers have been found to be better at comprehension monitoring while reading than poor readers (Baker, 1989; Pressley, Snyder, Levin, Murray, & Ghatala, 1987; for a review on metacognition and adult reading see Rinehart & Platt, 1984).

Metacognition is not just a result of learning, metacognitive skills have been found to be crucial to the processes of learning itself. Good learners treat learning as a purposeful, attention-directing, self-questioning act (Ganz & Ganz, 1990). Alderman, Klein, Seeley, and Sanders (1993) reported that journals of unsuccessful students indicated that they lacked metacognitive knowledge -- the students did now know why they were failing, and felt that they new the material better than they demonstrated. Improving students, on the other hand, demonstrated the clearest metacognition in their journals, focusing on evaluating their knowledge and strategies, providing evidence that metacognition is an important part of the learning process. Swanson (1990) found that subjects scoring higher on a metacognition questionnaire were able to derive solutions to basic chemistry and physics problems using fewer

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steps and with more efficient solution rates regardless of their cognitive ability. Pintrich and DeGroot (1990) found that self-reports of metacognitive activity during learning were positively related to academic performance in terms of seatwork, exams/quizzes, essays/reports, and average grade. Likewise, Pokay and Blumenfeld (1990) found self-reported metacognition to be related to end of semester achievement. As a variable important to learning, metacognition may be useful for trainers.

Recently, training researchers have begun to examine the use of metacognition as a way to evaluate and enhance training. Kraiger, Ford, and Salas (1993) suggest that since (domain specific) metacognitive skills are correlates of skill development, these metacognitive skills can be used as indices of learning for training evaluation purposes. Ford and Kraiger (1995) propose that metacognition should be considered and applied at several stages of training: needs assessment, design, and transfer. For example, needs assessment should identify which cues incumbents use in order to know when to apply their knowledge and skills. This can help to avoid production deficiencies in which the person knows how to do the task, but lacks the metacognitive skills that facilitate access to and use of this knowledge. Training design can encourage metacognitive development by including metacognitive objectives, encouraging self-directed learning, and allocating time during training for trainees to reflect on their learning. Finally, metacognition must be fostered which will allow generalization of knowledge and skills to the job. This includes encouraging active self-monitoring and hypothesis/strategy testing, as well as avoiding continual feedback which can interfere with the development of metacognitive skills such as self-assessment.

Thus far, the training literature has tended to focus on metacognition as an index of learning -- as something developed during training. The educational research cited earlier, however, demonstrates that the metacognitive awareness and skill is important to the learning process. Thus, the metacognitive knowledge and control possessed by the trainee at the beginning of training may impact how well he or she learns. The training literature, however, has not a yet addressed metacognition as an antecedent of training success, nor attempted to manipulate metacognition prior to skill acquisition. In fact, while the training literature has acknowledged metacognition as an important cognitive variable, the literature's treatment of metacognition has been primarily theoretical. Empirical research is needed to demonstrate whether or not enhancing the development of metacognition will enhance the efficiency or effectiveness of training.

Having knowledge of, and control over, one's cognitions allows one to allocate and use one's cognitive resources optimally. Kanfer and Ackerman, as well as Kuhl and Koch (1984) and F. Kanfer and Stevenson (1985), indicate that self-regulatory activity competes with on task activity, such as performing task functions or learning activities. However, recall that Kanfer and Ackerman (1989) indicate that when self-regulatory activity yields a net increase in resources devoted to the task the results should be *beneficial* to the learner. This is one reason metacognition is important to the learner. Metacognition may be used to ensure that the benefits of self-regulation outweigh the costs. The person can only devote enough resources if the person accurately gages task difficulty relative to their capabilities. Merely throwing resources at a task does not necessarily determine success -- the way in which the resources are used is also important. Metacognitive regulation in conjunction with metacognitive task knowledge allow one to evaluate what part or aspect of the task demands more attention so that resources are not wasted on irrelevant knowledge, information, or aspects of the task. Metacognition also allows one to monitor the strategies selected so that resources are not wasted on behavior that is ineffective or insufficient to complete the task.

Therefore, teaching metacognitive skills holds promise as an intervention from a limited resources viewpoint. Making these metacognitive skills more frequent, and perhaps more efficient and effective , can help the learner to more accurately gauge what deserves the investment of resources. It enables the learner to have a clear picture of what aspects of the task will require resources, what strategies will be effective based on these resource requirements, and what areas of the will need more attention. The learner can thus use what resources they have devoted to the task more efficiently, and gain more from their self-regulatory behavior.

The following section presents the conceptual model developed for the current study. This model specifies the linkages among the constructs examined. Specific hypotheses derived from this model are discussed.

## A Conceptual Model

Figure 1 presents a conceptual model developed for the current study. This model adds to the training literature in a number of ways. First, the model

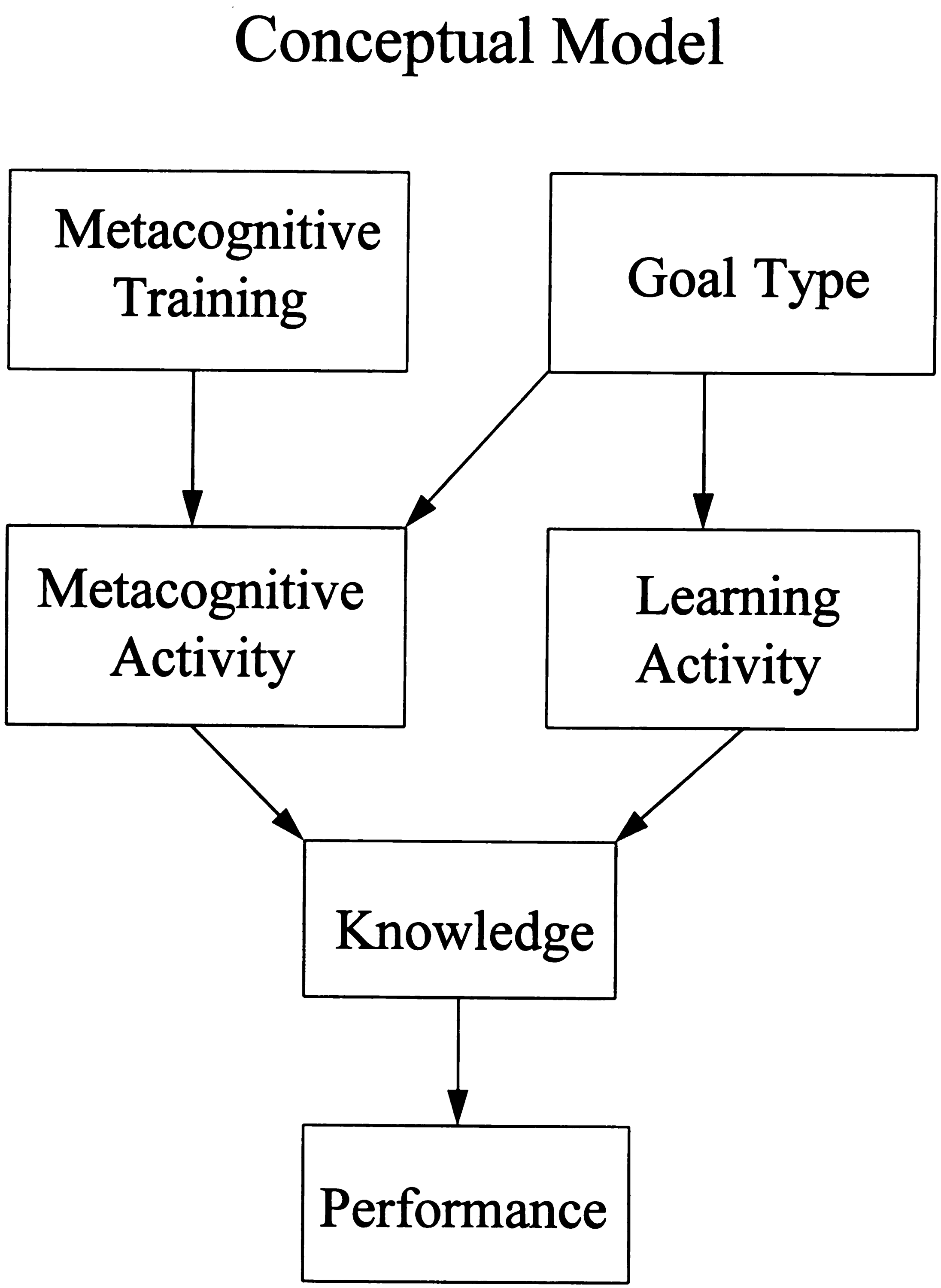


Figure 1-- The Conceptual Model

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demonstrates the way in which the two interventions discussed earlier, sequencing training through subgoals and metacognitive training, impact the acquisition of a complex skill in terms of both knowledge and performance by improving the way in which on task resources are used. Second, this model suggests increased specificity in what Kanfer and Ackerman (1989) have called "on-task resources." The model suggests two types of activities to which the resources allocated to skill acquisition can be devoted: self-regulatory activity (including metacognition), and learning activities. This model suggests that by helping learners to allocate their resources among these activities efficiently, and in proper sequence, the interventions can aid in the development of knowledge and performance. This section is an attempt to clarify the activities and purposes to which attention is devoted during the task.

On-Task Resources.

These activities are the processes which explain how resources affect learning. On-task resources are those resources devoted to acquiring the skill in question. These amount of resources devoted is determined by performance-utility allocation policies prior to engaging in the task as discussed by Kanfer and Ackerman (1989). That is, the individual determines the amount of resources to be devoted to the acquisition of a skill, and these resources are then subdivided between the various "on-task" activities as required by the tasks. While it may not be possible or even necessary to determine the exact amount of resources devoted each and every activity in which the learner engages, it is instructive to consider the types of activities that make use of "on-task" resources. To do so will clarify *how* interventions that free resources will enable the learner

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The activities to which individuals can devote "on-task" resources which aid in learning are comprised of two primary categories. The first of these categories is termed **learning activities** and include behaviors for the purpose of encoding, storing, and organizing knowledge and productions. This category includes task specific behaviors for the purpose of progressing through the task itself toward what has been called ultimate or end performance. The second category important to learning is **self-regulatory activities**, be they cognitive or metacognitive. These serve as support mechanisms monitoring and evaluating progress toward the goal, allocating resources, and evaluating and selecting strategies for goal attainment.

Learning Activities. Learning activities are those activities to which resources are devoted that aid directly in the encoding, storage, organization, and retrieval of knowledge. Some authors have referred to these activities as primary learning strategies or learning tactics (Dansereau et al., 1979; Dansereau, 1975; Wade, Trathen, & Schraw, 1990) though distinctions have been made between tactics and strategies. Tactics are individual techniques whereas strategies are collections of tactics employed in a learning situation, perhaps necessitating intention and purpose (Wade et al., 1990; Derry & Murphy, 1986; Paris, Lipson, & Wixon, 1983). The term "primary" distinguishes learning strategies that aid directly in the comprehension, encoding, storage, and retrieval of knowledge from other activities which may indirectly assist in learning (such as self-regulatory activity) which are termed supportive strategies (Dansereau et al., 1979). Both primary learning strategies and tactics are subsumed under what is being referred to as learning activities. The important feature is that learning activities are undertaken by the learner for the primary purpose of acquiring knowledge.

Literature investigating the strategies and tactics used to gain declarative or verbal knowledge has focused on learning from lecture or text sources. This research suggests many learning tactics and strategies used to learn information. Recently, research supports the notion that learning activities cluster in ways consistent with the theory that these strategies developed to help compensate for the limitations of humans as information processors. For example, learners compensate for limited processing capacity with integration tactics that chunk or link information. Likewise, learners compensate for the limited durability of information being processed by repetition, rehearsal or reorganization (DiVesta & Morena, 1993). While the specific names given to learning activities vary, there is considerable convergence as to the types of learning activities observed in learners of verbal information. Learning activities commonly observed or reported are: reading, reading slowly, mental repetition, imaging (creating a mental image), using analogies, summarizing, paraphrasing, listing, notetaking, organizing, charting, outlining, associating with previously acquired information, mnemonic devices, developing questions, restating in one's own words, linking ideas that relate in the material, marking important material by underlining or highlighting, and thinking about how to apply information (DiVesta & Moreno, 1993; Nist, Simpson, & Hogrebe, 1985; Simpson, Hayes, Stahl, Conner, & Weaver, 1988; Spring, 1985; Thomas, 1988; Wade et al., 1990).

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In addition to the activities used to learn declarative information, individuals will also devote resources to behaviors directed towards acquiring procedural knowledge, rules, or productions in skill acquisition. Consistent with Gagne's theory, Anzai and Simon (1979) found that subjects do in fact generate rules based upon experience with the task using information from prior learning and perception of current problem conditions. While the specifics of the strategies for learning rules will vary considerably with the task, there are strategies that learners can use to gain understanding of the procedural aspects of the task. Some strategies that may be used to generate rules are means-ends reasoning, experimentation by purposefully making mistakes, experimentation by purposefully performing different behaviors or choosing different options to add variability to a task. The learning activity directed at procedural learning may be differentiated from simple task-function activity by differences in task behavior such as increased variability in the selection of task practice options, more practice of behaviors that will lead to success in the long term (Ford, Smith, Weissbein, & Gully, 1995), less taking the task to its completion, and more time to complete the task. The activity is less directed at attaining high performance, and more directed at acquiring knowledge and a deeper understanding of the relationships among task elements.

Self-Regulatory Activity. Kanfer and Ackerman (1989) treat resources devoted to self-regulation as neither on-task nor off-task. In the current model, self-regulatory activity is being considered as a consumer of "on-task" resources since self-regulation competes with the resources devoted to acquiring and performing the skill. If resources are either on-task or off-task (and, really, these are mutually exclusive categories) than the self-regulatory activity involving activities demonstrated to be important to learning must be considered to be part of the on-task resources. While they are on-task resources, they are not primary learning activities. Self-regulation activities are considered separate unto themselves, but playing a vital supporting role in the learning and performing of skills. For evidence that self-regulatory activity plays a supportive role as opposed to a primary role, one need only consider Kanfer and Ackerman (1989) in which they demonstrate that when there is competition among activities, self-regulation diminishes in favor of other activities.

Just as goals can be set either around learning or performance, self-regulatory behavior can focus on learning or performance. Metacognitive self-regulatory activities can involve the evaluation of one's own state of learning, evaluating the task demands, and evaluating one's learning strategy (Bieman-Copland, 1994; Danereau, 1979; Flavell, 1987). Since a learning goal is to reach a cognitive state where the information and rules are developed, encoded, organized, stored, and can be retrieved, awareness and on-line evaluation of whether this goal is being met is metacognitive. An example is a learner's self-assessment that he/she is ready to take a test, or the so-called "judgments of knowing" or "feelings of knowing" (Nelson, Dunlosky, Graf, & Narens, 1994). There are many tactics that have been identified which may be performed to aid learners in determining the resource demands of the task and to assess where they have breakdowns in their learning. For example, surveying the material to determine what may be difficult to learn, self-testing, or reciting material to look fo

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look for holes in one's learning are just a few examples of activities undertaken to aid in self-assessment and regulation (DiVesta & Morena, 1993; Nist, Simpson, & Hogrebe, 1985; Simpson, Hayes, Stahl, & Weaver, 1988). These metacognitive assessment activities are so accepted by the educational literature as important support strategies to learning that many of them are built into learning/study programs like SQ3R (Peterson, 1941) or PORPE (Simpson, Hayes, Stahl, & Weaver, 1988). Likewise, Thomas (1988)includes self-assessment, cognitive monitoring, and strategy selection as important components in his model of an ideal student.

Self-regulation also plays an important role in performance across a variety of tasks. The self-regulatory activities of monitoring performance, assessing current status relative to one's goals, and reacting to this status appropriately are an important part of reaching performance goals given sufficient resources. Activities such as obtaining or checking feedback and reviewing the goal are important activities for determining how performance is progressing, and evaluating the required effort. Metacognition plays a lesser, but important part in this self-regulation through strategy evaluation and selection. Effective learners and performers must check their progress and assess their strategy to ensure that it is effective. Failures to change strategies or changing strategies too soon can result in poor performance (Earley, Connonlly, & Ekegren, 1989). Self-regulatory behavior, be it cognitive or metacognitive, plays an important role in support of both learning and performance activities involved in skill acquisition.

Linkages

Based upon the supportive literature discussed thus far, the current model is presented to clarify how sequencing training through subgoals and metacognitive training can affect learning during skill acquisition. The model suggests that skill is determined primarily by the acquisition of knowledge (in terms of declarative knowledge and procedural knowledge). Knowledge acquisition is affected directly by the amount of learning activity and metacognitive activity performed by the individual. This learning activity is determined by the type of goal the learner is pursuing, be it an outcome oriented goal, or a set of sequenced subgoals. The amount of learning focused self-regulatory activity the learner engages in is determined by both the type of goal, and whether or not the learner has received some metacognitive training prior to skill acquisition. Therefore, the effects of metacognitive training and goal type on knowledge and skill are expected to be mediated by the amount of learning activity and metacognitive activity. These linkages are explained below, and specific hypotheses are offered.

In their review of the goal setting literature, Locke, et al. (1981) indicate that one of the major purposes of a goal is to direct effort. In short, people put effort toward behaviors for which they have a difficult, specific goal more than behaviors for which they have no goal, or a "do your best" type of goal. People with performance goals will devote their resources to activities that are consistent with this type of goal. This means that they will have to divide their resources between a number of different activities. People with performance goals will direct their effort toward achieving the

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final performance goals, but must concurrently attempt to learn the declarative knowledge and procedures needed to perform, self-regulate to the goal, engage in metacognition regarding their learning, and perform the task as best they can. Thus there is considerable division of the resources. This division of resources means that the individual has fewer resources available to devote to learning activities which are intended specifically for the encoding and storage of declarative information, or the generation of procedural if-then rules. Individuals with performance goals are likely to rely on repeated exposure to the material to bring about learning rather than devoting resources to learning activities.

On the other hand, it is possible to set subgoals which sequence training for the learner in light of instructional sequencing theory. One advantage to be gained using subgoals is that the learner's resources are focused onto a smaller portion of the task. This should to lead to better performance, and more self-regulation since more resources are focused on what amounts to a smaller task. This is similar to the idea behind part task training (Naylor, 1962) in that the task is, in effect, broken down into subtasks with each smaller subtask able to receive the learners full attentional resources. Part task training generally involves practice on some subset of task components prior to practice on the whole task (Proctor & Dutta, 1995). Wigtman and Lintern (1985) identify three basic methods of task decomposition for part task training: segmentation in which the whole task is broken down along spatial or temporal lines, fractionation which involves breaking a task into components performed concurrently, and simplification in which training is performed on a simplified version of the task.

Subgoals and part-task training operate to some degree on the same principles in that the task is in effect divided up so that resources can be devoted to a smaller portion. However, sequencing subgoals do not involve a previous practice period. Subgoals are set prior to practice on the whole task to direct the effort of the practice. In addition, sequencing subgoals do not divide the task along the dimensions such as time, concurrence, or space. Instead, the subgoals divide the task according to the sequential learning tasks between initiating learning and automaticity that must be accomplished, i.e. gaining declarative knowledge, gaining procedural knowledge, and finally performing at a superior level. Therefore, sequencing subgoals are not equivalent to traditional part-task training. In addition, subgoals should offer advantages over simple part-task training on a number of counts. First, sequencing subgoals require no pre-training which can be costly in terms of time and equipment. Secondly, subgoals do not break the task apart into small behavioral components that must be re-integrated, but sequentially guide the acquisition of knowledge which builds upon itself to create fast, accurate performance. In this way, sequencing subgoals should avoid the difficulty persons trained using some part-task methods encounter when attempting to recombining the various task components on the whole task, particularly for complex task with high component integration (Naylor and Briggs, 1962).

By focusing resources on a smaller portion of the task, sequenced subgoals allow for more learning activity. Rather than asking the learners to perform multiple tasks simultaneously -- encode declarative information, determine task procedures, perform at a maximal level, and self-regulate -- sequenced subgoals divide the task into more manageable parts for the learner. The main hurdles in skill acquisition that must be accomplished prior to smooth accurate performance are learning declarative and procedural knowledge (Anderson, 1982; Kanfer & Ackerman, 1989; Gagne, et al., 1992). Subgoals should be set to direct the learner to focus all of their resources on sequenced steps to attaining smooth accurate performance. The subgoals allow the learner focus on the sequential learning tasks and to build upon previous learning as they progress. Rothkopf and Billington (1979) demonstrated that learning goals were useful in the directing of effort. Likewise, Hofmann (1993) suggests that learning goals help to avoid detrimental cognitive interference, such as that which occurs when the learner is faced with numerous competing demands. Subgoals encourage learners to first learn the necessary declarative knowledge, then the procedures, and only then -- after a solid foundation has been laid and resources freed from this learning -- are performance goals given. This sequencing of goals encourages learning activity by placing the primary focus early in skill acquisition on learning not performance, and in directing the allocation of resources to activities which enhance learning. In addition, properly sequenced subgoals divide the task into more manageable subtasks, making the learning needed to meet each goal manageable. This should to free enough resources for the necessary learning activity. These subgoals are arranged such that later goals take advantage of the resources freed due to prior learning. Therefore, it is hypothesized that the amount of learning activity undertaken by the individual will be affected by the type of goal they have been assigned. Stated explicitly:

Hypothesis 1: People given subgoals will engage in a significantly greater amount of learning activity than will those pursuing performance goals.

In keeping with the distinction made between primary and supportive activity, in the current model self-regulatory activity is considered separately as activity which plays an important support role in learning and performance. Metacognitive training should enhance on-task metacognitive activity devoted to learning. By making subjects more aware of the importance of metacognitive activity to learning, these skills should be viewed as worthy of resource devotion. Plus, as with any skill containing consistent elements, providing practice in important metacognitive skills should decrease the cognitive resources that are required to perform such self-regulatory activity (Norman & Bobrow, 1975; Shiffrin & Schneider, 1977). Several authors including F. Kanfer and Stevenson (1985) and Kanfer and Ackerman (1989) have suggested that training in self-regulatory activities may reduce the amount of attentional resources required by these self-regulatory activities. A third potential benefit of training is that it may improve the quality or accuracy of metacognitive activities.

Because metacognition plays a large role in learning, training in these skills is likely to result in increases in metacognitive activity in support of learning. Indeed the literature on metacognition suggests that it is an area in which improvement is often necessary. While metacognition develops in all individuals until the end of elementary school and perhaps beyond (Brown, 1978; Fingerman & Perlmutter, 1994), metacognitive skill may vary more between individuals than other cognitive variables like memory, and may be a major determinant of success in several skill areas (Redding, 1990). In addition, research indicates that these metacognitive differences are not merely accounted for by differences in ability, as they exist even after controlling or matching for ability (August et al., 1984; Swanson, 1990).

Efforts to train metacognition has produced encouraging results in educational settings (Ryder, Beckchi, & Redding, 1988). Redding (1990) concludes that metacognitive skills can be readily taught and learned. To wit, many studies have had success improving learning or performance by training metacognitive skills, or using interventions to increase metacognitive activity (Pressley, et al. 1987; Bean, Singer, Sorter, & Frazee, 1986; Lorenc, Sturmey, & Brittain, 1992). While some researcher are of the opinion that to train a cognitive skill completely requires long term training over weeks or months, smaller shorter interventions have proven effective at increasing metacognition and subsequent performance (Pressley et al., 1987; Lonrenc et al., 1992). Therefore, training individuals to be aware of their own metacognitive processes, and to use these metacognitive skills to aid learning will reduce the resources needed to perform these activities, increase the use of these activities, and increase the skill with which they are used. The next hypothesis follows:

Hypothesis 2: Metacognitive training will be positively related to metacognitive activity performed in support of learning. Individuals given such training will report and demonstrate greater use of metacognitive activity to assess and optimize their learning.

Another variable expected to have impact on the amount of metacognitive activity is goal type. It is likely that those with subgoals will perform more metacognitive activity, and those with performance goals will perform less. This is the case for two basic reasons. First, performance goals both direct the individual away from learning activities, and spread the resources of the learner across a number of different activities. In attempting to perform on the task prior to compilation one must learn information necessary for performance, attempt to perform on the task, and attempt to self-regulate. This spreading of resources may create a situation in which there are insufficient resources available to allow metacognitive activity through much of the task and it will be diminished in favor of other activities. A second reason individuals given a performance goal may not engage in as much metacognitive activity is that the performance goals they are given do not direct their resources toward learning, acquiring information, or assessing their state of knowledge. Performance goals are likely to lead to self-regulation (when it occurs) around performance itself, and not assessment of one's own knowledge or strategy.

In contrast, individuals receiving sequenced subgoals should engage in more metacognitive activity. Subgoals focus on learning and thus should direct attention toward learning activities, and self-regulation that supports such learning. Not only should subgoals focus the individual on learning, but more resources should be available to allow for such regulation. Since subgoals focus on a particular subportion of the skill acquisition task, and the subgoals are sequenced to allow prior learning to free resources later in skill acquisition, the learner will have more resources available to devote to self-regulation at each stage, early as well as late. One can interpret Kanfer and Ackerman's (1989) third study in this light. They trained the subjects on either declarative or procedural part task training and both were effective in bringing about improvements in score which indicated that the people learned the part task training and could apply this learning to the task. In effect, the authors increased performance by setting subgoals for a particular part of the task.

Not all subgoals are equal. While both declarative and procedural training increased subjects' score, only declarative training freed enough resources to allow self-regulation regarding the end performance goals set by the authors. This is probably because the procedural goal was out of sequence, in order to perform the subjects needed to devote resources to learning the declarative information before procedural learning could free enough resources to encourage self-regulation. The resulting hypothesis is:

Hypothesis 3: Sequenced subgoals lead to more metacognitive activity in support of learning than will performance goals.

The previous two hypotheses suggest that it is possible that metacognitive training and goal type will interact to determine the amount of metacognitive activity that takes place on the task. That is, although metacognitive training is expected to increase this activity, the type of goal one has may act to determine the effectiveness of this training. Those with only metacognitive training would be expected to demonstrate increased metacognitive activity given this training. Sequenced subgoals that focus resources on learning should yield more free resources faster. These free resources are available for devotion to metacognitive activity. Therefore, those with subgoals should benefit more from metacognitive training since they have the resources available to transfer this training to learning on the task. In contrast, those with performance goals are directing their resources toward performance. These individuals are in effect dividing resources among the aforementioned activities leaving insufficient slack resources to devote to self-regulation. Thus, the metacognitive training they receive will have no effect on the amount of metacognitive activity in which they engage.

However, this hypothesis is more exploratory because individuals may react differently to the performance goal-metacognitive training combination. Metacognitive training is encouraging them to expend resources on learning supportive activities, while the performance goals are encouraging them to devote their resources away from learning activity and learning supportive self-regulation in favor of performance activity and performance supportive self-regulation. Some learners may react stronger to the performance goals and thus the potential interaction is expected. However, others may react to the training by engaging in more metacognitive activity despite their performance goal. This would be expected to have negative impact on the effectiveness of their performance goal, and a yield a moderate amount of metacognitive activity.

> Hypothesis 4: Metacognitive training and goal type will interact to determine the amount of metacognitive activity devoted to learning. Those with sequenced learning subgoals will engage in more metacognitive activity as a result of training, those with performance goals will not demonstrate an increase in metacognitive activity.

The next linkages proposed by this model are the linkages between learning activity and metacognitive activity with the acquisition of knowledge. The on task-activities outlined here are each expected to relate positively to the acquisition of knowledge, both declarative and procedural. Learning activities are performed specifically with the intention of increasing knowledge. These activities aid directly in the encoding, storage, organization, and retrieval of knowledge. Devoting resources to studying, memorizing, developing mnemonics, and other such learning activities are expected to increase declarative knowledge. Similarly, exploring the task to gain an understanding of the relationships between task elements is expected to increase the procedural knowledge associated with understanding if-then relationships.

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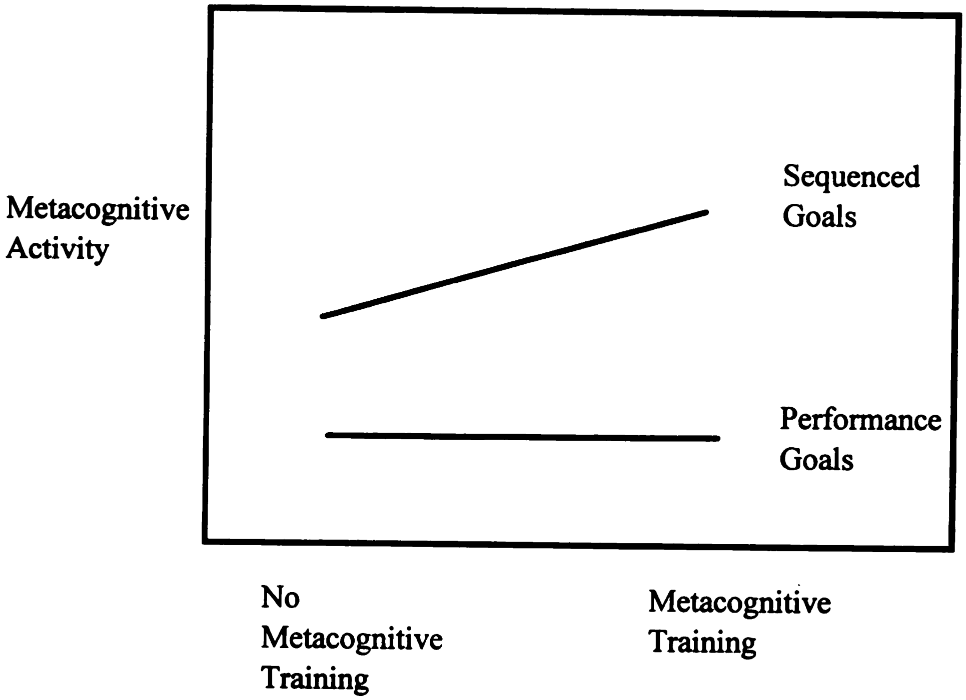


Figure 2 -- Theoretical Relationships For Hypothesis 4

Hypothesis 5: Increased learning activity will lead to increased learning in terms of declarative knowledge, procedural knowledge, and skill performance.

Based upon the previous review of the literature, metacognitive activity is also expected to increase learning in terms of declarative and procedural knowledge. As discussed earlier, metacognition has been found to be related to learning in a number of studies both in the classroom (Sinkavich, 1990; Alderman, Klein, Seeley, & Sanders, 1993; Nelson, Dunlowsky, Graf, & Narens, 1994; Vadhan & Stander, 1994; Rinehart & Platt, 1984) and out of the classroom on tasks such as learning to use medical decision making software (Ridley et al., 1992), electrician performance (Mikulecky & Ehlinger, 1986; Ganz & Ganz, 1990), and computer programming (Etelapelto, 1993). Metacognitive skills like self-assessment or strategy evaluation are important to learning. Those who engage in more of these activities are likely to gain understanding regarding where gaps in their learning exist, how to fill them, and when a learning strategy is not optimal. These advantages to performing metacognitive activity should ultimately enable persons engaged in more metacognitive activity to have more complete knowledge of the task.

Hypothesis 6: Metacognitive activity will be positively related to knowledge. People engaging in more metacognitive activity will demonstrate increased declarative and procedural knowledge.

Finally, the current model suggests that this increase in knowledge is hypothe

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hypothesized to translate into increased performance on the skill being learned. Kraiger et al. (1993) suggest that learning is not unidimensional, but consists of cognitive, skill based, and affective dimensions. The current model acknowledges the multidimensional nature of performance, and suggests that the development of better knowledge based outcomes (declarative and procedural knowledge) will lead to better skill based outcomes. This is the case for two reasons: 1) skill based outcomes such as reaching automaticity necessitate successful compilation of the declarative knowledge and procedures making the acquisition of this knowledge vital to rapid performance, and; 2) it is not enough to automatize any procedures, the best performers will automatize the most efficient and accurate procedures. Athletic coaches have acknowledged this truth by updating the trite saying "practice makes perfect" to "perfect practice makes perfect". The learners must gain enough knowledge to enable the automatization of the fastest most accurate procedures possible. Particularly for more cognitively complex tasks, the degree to which one has knowledge of the task will determine how effectively the skill can ultimately be performed. Many studies have verified the knowledge to performance relationship across a wide variety of tasks. As studies of job performance have attested, job knowledge is one of the best predictors of performance (Hunter, 1986) .

Hypothesis 7: Knowledge will be positively related to skill performance. Individuals demonstrating higher levels of declarative and procedural knowledge will exhibit better performance.

The current model also suggests that the effects of metacognitive training on knowledge acquisition are fully mediated by the metacognitive activity demonstrated by the learner. That is, metacognitive training should increase the amount and quality of metacognitive activity on the task. This increase in metacognitive activity will in turn impact knowledge, and knowledge will impact skill. Metacognitive training is not expected to have any direct impact on knowledge acquisition or skill performance other than the influence of this training on metacognitive activity.

Hypothesis 8a: The effects of metacognitive training on knowledge acquisition will be fully mediated by the impact of this training on metacognitive activity. Metacognitive training will not directly affect the acquisition of knowledge.

Hypothesis 8b: The effects of metacognitive training on skill performance will be fully mediated through effects of this training on metacognitive activity, and metacognitive activity's affect on knowledge development.

Likewise, the effects of goal type on knowledge acquisition and performance are expected to be mediated through their effects on metacognitive activity and learning activity. That is, goal type is not expected to have a direct impact on learning nor performance other than the influence which comes through goal type's effects on learning activity, and metacognitive activity, and their effects on knowledge acquisition, and ultimately skill. Thus the final hypotheses are offered:

Hypothesis 9a: The effects of goal type one knowledge acquisition will be fully mediated by the effect of goal type on the learning and metacognitive activity. Goal type is not expected to exhibit direct effects on knowledge acquisition or performance.

Hypothesis 9b: The effects of goal type on skill performance will be fully mediated through effects of this training on learning activity, metacognitive activity, their effects on knowledge development. Goal type is not expected to exhibit a direct effect on knowledge acquisition or performance.

# METHOD

Sample and Design.

Participants were undergraduates at Michigan State University enrolled in introductory psychology courses. They received extra credit for their participation in this experiment.

The study is a 2 (goal type) X 2 (metacognition training) fully crossed factorial design. The two levels of goal type are sequenced subgoals and performance goals. The second factor reflects the presence or absence of metacognition training prior to task engagement.

A power analysis was conducted to determine the sample size required to detect a moderate effect size with a power of .80 and a significance level of .05 (Cohen, 1977). For a 2 X 2 factorial design, cell sizes of 20 will result in a power of .80. Therefore, the goal of the study will be to have 20 subjects in each cell yielding a total sample size of 80.

The Task.

The task is a revised version of the computerized radar simulation named TANDEM (Tactical Naval Decision Making System; Dryer, Hall, Volpe, Cannon-Bowers, & Salas, 1992). TANDEM depicts targets on a radar screen. Trainees are placed in the role of Radar Operator of a U.S. Navy Aegis-class cruiser. Using a mouse, the operator chooses which targets to "hook" and collects information about the target from pull down menus. This information is compared with preset ranges and combined in order to classify the target's Type, Class, and Intent. Having made these classifications, the Operator must then decide to shoot hostile targets and clear peaceful targets from the screen. The goal of the task is to correctly select, classify and process targets as efficiently as possible. Operators must learn how to prevent targets from entering critical zones surrounding their ship. If targets are allowed to penetrate these "penalty circles," points are deducted. Individuals must learn to check the speed and range of targets to prioritize them and determine an order of engagement. Subjects are presented with a series of scenarios that vary in the number of targets and proportion of targets that threaten to penetrate the penalty circles. The scenarios were designed to have roughly equal complexity in terms of number of targets, number of targets threatening the penalty circles, ambiguity in the cues, and the need to zoom in or out on the screen to identify appropriate targets.

Procedure

When subjects arrived, they read and signed the consent form that described the experiment (See Appendix A). Next, they completed a demographics questionnaire which measured possible confounds such as experience with the task or time spent playing video games (See Appendix B), as well as the Wonderlic as a measure of cognitive ability to use as a co-variate since Kanfer and Ackerman suggest that those with higher cognitive ability have a greater pool of resources from which to draw. Next, subjects in the metacognitive training group received the metacognitive training (see Appendix D). The experimenter read through the training with them and took them through the exercises. The control subjects did the same exercises, but no reference to metacognition was made.

After a five minute break, the participants began the process of learning TANDEM. Participants started with a brief demonstration regarding how to use the mouse and perform the mechanics of the task, including cue ambiguity and penalty circles.

After this introductory session, participants were given their first goals to allow the learning/performance goals to take affect. Learning goal participants were told that their job through the study session and next two trials was to commit to memory the cue values and other specific, relevant information. Many learning goals suffer from being too general, therefore these learning goals attempted to be as specific as the "difficult, specific" performance goals. It was emphasized that learning the declarative information, not scoring well, was what they were being asked to do for the first two scenarios. Performance goal people were told that they must try to reach a particular performance goal (determined by pilot testing) that represented the 90th percentile on each of the first two sessions, and they must "prepare themselves" to do so during the next few minutes, and then attempt to reach their goal. The 90th percentile was chosen for two basic reasons. First, goal setting research has demonstrated that effective goals are difficult and specific, but not beyond the ability of the subject (Locke et al., 1981). A 90th percentile goal, therefore, represents a level that ten percent of a similar population ("do your best" pilot subjects) were able to reach, making this goal difficult but not impossible. The second reason this goal was chosen was to be consistent with the prior research of Kanfer and Ackerman (1989) who used 90th percentile scores as difficult, specific performance goals.

After a goal commitment measure (see Appendix G), they were given 15 minutes to read/study the material. They were told that they may write on the material at any point during the experiment. Finally, subjects had their goals re-stated and the metacognitive training subjects were reminded to try to use what they learned during training to help them. The subjects then engaged in two seven minute scenarios.

Next, the second goal manipulation was given (see Appendix F). The sequenced subgoal group was given instructions to try and learn the rules of the task. To try and grasp "if-then" relationships between task elements. The performance goal group was given a second performance goal indicating the 90th percentile (as determined on a pilot test) for the task. The goal commitment measure followed goal assignment. The participants then performed two more seven minute scenarios.

After a short break, a final set of performance goals was given to all of the participants. They were told that their performance on the final scenario is the final "test" of how well they have learned the task. All participants got performance goals that represented the 90th percentile for the last three scenarios. The goal commitment measure was given once again following this manipulation. The final two scenarios were seven minutes each. Performance measures taken from the final scenario were considered "end of training performance."

Following these scenarios, participants were given questionnaires to evaluate how much learning activity and metacognitive activity they performed. Upon completion of the measures, participants were debriefed, given a debriefing sheet (found in Appendix K), and dismissed from the experiment.

Goal Type Manipulation

The goal type manipulation involves the type of goal assignment that is given to each of the participants. Participants in the performance goal condition received goals which are difficult and specific indicating a score to achieve for the scenarios which follow. As with previous research (e.g. Kanfer & Ackerman, 1989) the goals were set between a small set of trials rather than before each and every trial. Performance goals were set to capture the 90th percentile of performance scores determined by pilot testing consistent the operationalization of difficult, specific performance goals used in previous research.

Participants in the sequenced subgoal manipulation received goals which attempted to capture the learning sequence implied by Gagne and associates (Gagne et al., 1992). First, a declarative learning goal was set. Subjects were told to focus on learning as best they can particular facts and information about the task. Particularly, the subjects were told to learn the cue values and penalty circle locations (see Appendix F). This goal represented a specific and moderately difficult goal which captures declarative learning needed for performing the task (i.e. facts and information).

In keeping with the hierarchical sequencing notions of Gagne et al. (1992), the second goal for the sequenced subgoal group attempted to direct their attention from declarative knowledge to procedural knowledge. The second goal for the sequenced subgoal group was therefore to learn the relationships between task elements. This focuses participants' cognitive resources on the procedural elements of the task. These subjects were asked to derive "if-then relationships" between task elements. To lend increased specificity to this goal, and to aid subjects in understanding what they are being asked to do, a list of several "if" beginnings was provided so that the participants were asked to finish the sentence with the "then" half. Subjects in this condition were asked to write down as many of these rules as they could following the two sessions under this goal condition.

Finally, for their third goal manipulation, the sequenced subgoal group was given a performance goal. This goal was identical to the goal for the performance goal group, and represented the end of the progression of goals from declarative learning to procedural learning to performance (see Appendix F for the goal manipulations).

Metacognitive Training

The metacognitive training manipulation is directed toward teaching participants about metacognition, emphasizing its importance, and giving practice at metacognitive activity. The program was designed to elucidate the issues, to clarify them, and make processes that likely have gone unattended more salient. Practice was given so that the subjects could become comfortable thinking about these topics and working with these issues. Ideally, this training would work toward bringing metacognitive procedures that work toward automaticity. However, as a first step, the trainin

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training was an attempt to increase the amount and quality of metacognitive activity. Recall that the theory predicts that sequenced subgoals should free sufficient resources for this metacognitive activity without being detrimental to learning and this should benefit performance.

The first part of the training was concerned with teaching individuals to plan their learning. This includes identifying which elements of the task are difficult and require more resources or a different strategy. Practice tasks were given, allowing participants to practice identifying which type of material would be difficult to learn. Participants were presented with several opportunities to assess material to determine which aspects they think were most difficult to learn (and thus require the most attention) and explain why they make this assessment. The training also encouraged individuals to think about what they could do to aid in learning the difficult material.

Next, the training encouraged individuals to evaluate their learning in terms of how well they need to know material against how well they actually know it. This part of the training directed people to determine what the goal of their learning is, and then to make sure that they have reached this goal. Exercises were designed to help individuals see the importance of clarifying goals and invoking evaluation methods, like self-testing, to evaluate their learning. This was done by first focusing participants on assessing how well they need to understand the material. Several questions were given as examples of the types of questions they needed to address. Next, the training provided the participants with two opportunities to attempt to learn information and decide when they knew it well enough to answer questions about the material. Self-testing was recommended as a strategy to monitor and promote metacognitive knowledge. Questions are provided to give them feedback as to whether they adequately knew the material, and were thus correct in their self-assessments.

Finally, the training encourages participants to think about strategy evaluation. This training encourages the participants to: clarify what strategy they are using, evaluate whether the strategy is working, and consider how much time the strategy should need to work. Exercises were designed to help individuals to examine strategies, and think about the issues regarding strategy evaluation. Participants were given a problem and asked to first generate as many possible strategies for solving the problem as they can. Then they were asked to evaluate their strategies by ordering them from best to worst (See Appendix D).

In order to ensure that all effects are from the focus on metacognition in the metacognitive training, and not simply engaging in the excercises, the people in the non-metacognitive training conditions took part in the exact same activities as the metacognitive training group. Non-metacognitive training subjects were told that these extra activities are necessary to allow the experiment to last as long as other experimental conditions so everyone gets the same credit. Participants were told that these excercises are being tested for another study, and the experimenter was interested in their opinion of the difficulty of the exercises. No mention of metacognition or self-regualtory activity was made to the non-metacognitive training group.

Pilot Studies

Two pilot studies were conducted for this experiment. The first pilot study focused on evaluating/fine tuning the metacognitive training. Approximately ten participants were given metacognitive training. After a task demonstration they were asked to study the task material for 15 minutes and perform the task scenarios. During the scenarios, the subjects were stopped every 1.5 minutes and asked to describe what they were thinking. The experimenter transcribed their statements. Following the scenarios, participants were given the metacognitive questionnaire and asked to discuss the metacognitive training regarding whether it enhanced the quality or amount of metacognition, whether was too difficult or easy, and whether it needed improvement. They were also asked if they found the metacognitive training useful for learning the material. Any marks made on the material were evaluated as to whether these marks were useful to support self-report measures of metacognitive or learning activity. This first pilot study indicated that subjects did not find the initial version of the metacognitive training very helpful, they felt it did not apply since the material and task were very different. They expressed few metacognitive statements during the scenarios. The metacognitive training was rewritten, and the pilot rerun. The subjects generally were more positive to the new training, reporting that it was somewhat helpful in thinking about how to approach learning the material, and evaluating their strategies. They appeared to mention metacognitive activity from the training more during the task, though few such statements were made relative to target assessment or other task activity. Very little writing on the material occurred during the pilot studies.

The second pilot study ascertained 90th percentile scores for each of the 6 scenarios, and assessed the timing of the experiment. Participants were given no metacognitive training and "do your best" goals. After an introduction and task demonstration, participants had fifteen minutes to study the material and then performed the scenarios. All measures were given in their appropriate places in order to evaluate the psychometric properties of the measures, and the timing of the experiment. The subjects' mean scores on the metacognitive questionnaire were compared to assess whether the metacognitive measure was being strongly impacted by demand effects from the metacognitive training received by the first group. No such effects were found. In fact, the group without the training received slightly higher scores on the questionnaire.

The data from the pilot tests was also be analyzed to examine the reliability of the learning activity, metacognitive activity, and goal commitment scales. Slight improvements were made to these measures as appropriate.

Measures

Cognitive Ability. General cognitive ability was assessed using the Wonderlic Personnel test. This short form cognitive ability test consists of fifty items arranged in order of difficulty. Item content includes word comparisons, disarranged sentences, sentence parallelism, following directions, number comparisons, number series, analysis of geometric figures, and math or logic story problems. Subjects were given 12 minutes to complete as many items as possible. Scores on the Wonderlic test are highly related to scores on longer tests of cognitive ability. In addition, the test-retest reliabilities have ranged from .82 to .94, and internal consistency reliabilities (based on odd-even correlations) have ranged from .88 to .94 (Wonderlic Personnel Test & Scholastic Level Exam User's Manual, 1992).

Demographics. Subjects answered questions regarding their age, sex, GPA, previous lab experience, and previous video game experience (see Appendix B).

Goal Commitment. Goal commitment was measured with a three item scale using Likert type items adapted from Kanfer and Ackerman (1989). The items ask about how willing the participants are to work hard, put forth effort to reach the goal, as well as how committed the subjects are to working as hard as possible to reach the assigned goal. Coefficient alpha measures of internal consistency reliability for the scale reported was .61, .81, and .82 on experiments one, two, and three respectively. Consistent with the scale's use in the past, goal commitment was measured after participants received a new goal, before engaging the task. Note that participants saw and performed a demonstration and material and thus had some exposure to their task prior to answering goal commitment questions. Specific items can be found in Appendix G.

Metacognitive Activity. Metacognitive activity was measured by a 13 item self-report measure developed for this study. This scale measured the extent to which subjects performed metacognitive activities that are important to learning and performance. These include planning, previewing material to determine resource requirements, marking difficult material, self-testing and learning evaluation, and strategy selection and evaluation. Subjects were asked to respond on a 7 point Likert type scale from Strongly Agree (1) to Strongly Disagree (7) with first person statements regarding weather they performed specific metacognitive activities and behaviors. These items are found in Appendix E.

As reactivity may be a concern, a more non-reactive measure was gathered to corroborate the self-report data. One way to do this is to ask an open ended question such as "what did you attempt to do on the last trial?" This question was asked *following* each trial so as not to induce metacognitive activity. The answers were examined, coded by multiple coders as to the amount and quality of metacognitive self-assessment reflected in the answers. Inter-rater reliabilities were then established. See Appendix J for the basic open ended question and answer sheet. Instructions to raters can be found in Appendix L.

Learning Activity. Self-reported use of learning activities was also measured with a scale developed for this study. This scale assessed the degree to which individuals engaged in activities which aid directly in the encoding, storage, organization, and retrieval of knowledge. The scale is arranged in series of Likert type items on a 7 point scale which ask the participant to indicate the extent to which he or she engaged in activities such as mental rehearsal, listing, underlining, using mnemonic devices, or associating material with previously learned material. In addition, the scale asks the degree to which the participant engaged in task specific learning such as engaging targets just for practice (as opposed to attempting to score), or experimenting with new strategies. The specific questions are in Appendix I.

In addition, as a way to substantiate the self-report, participants will be asked after each trial what they had attempted to do during that trial. This information was examined by quantifying the number of learning activity statements made. This information was correlated with the self-report measure to corroborate the self-report.

Knowledge. Knowledge as assessed prior to the final scenario. Knowledge was measured with a multiple choice knowledge test that measures declarative and procedural knowledge. Declarative items ask for simple facts or information such as cue values. Procedural knowledge items were designed to tap a persons understanding task element relations using if-then production based questions. These questions require test takers to evaluate situations and choose the best option. The knowledge test is in Appendix H.

Performance. A number of performance measures were collected from the final practice scenario. As this study is interested in training efficiency, that is, learning more in an equal amount of time, the final practice scenario is an appropriate source of the performance data. Participants received 100 points for targets if they correctly determine the type, class, intent, and engagement. Participants lost 100 points if a target penetrated the outer penalty circle, and 50 points if a target penetrated the inner penalty circle. Measures which indicate the speed, accuracy, prioritization, and efficiency of the participants were collected by the computers and used as performance data. These measures include final score, number of targets engaged, number of zooms, number of speed queries, number of range queries, number of penalty circle intrusions, and accuracy of engagement.

Data Analysis

The psychometric properties of the metacognitive activity, learning activity, goal commitment, and knowledge test scales were assessed prior to testing the conceptual model.

The hypotheses in this study were tested using hierarchical regression. Hierarchical regression can be used to test the mediating hypotheses proposed in this study. To do so, first the two direct links must be demonstrated. The independent variable must have an effect on the mediator, and the mediator must have an effect on the dependent variable. Next, a relationship must be demonstrated between the independent variable to the dependent variable. Finally, the mediator is entered first (partialled out) and then the effect of the independent variable on the dependent variable is reassessed. When the mediator is partialled out the relationship between the independent variable and the dependent variable ought to diminish in a partial mediation or disappear in a full mediation. The regression analyses are outlined in Table 1. Cognitive ability and goal commitment for the final performance goal (the goal equivalent for both groups and relevant to the dependent variable) were entered in the first step for each regression as control variables.

The first regression analysis examined the effects of metacognitive training and goal type on metacognitive activity as measured by the self-report scale (hypotheses 2, 3, and 4). Comparisons between the goal types and the presence/absence of metacognitive training were contrast coded (Cohen & Cohen, 1983). Cognitive ability was entered on the first step, the second step contained metacognitive training and goal type, and the third type contained the interaction between goal type and metacognitive training.

The second regression assessed the effects of goal type on learning activity (hypothesis 1). Cognitive ability and goal commitment were entered on the first step, and goal type was entered on the second step. Dummy coding for goal type allowed this regression to examine whether people with sequenced subgoals performed more learning activity after partialling out ability and goal commitment.

Regressions one and two was also run with the post-trial measures of metacognitive activity and learning activity (assuming these can be reliably coded) as the dependent variables.

Regression three assessed the impact of metacognitive activity and learning activity on knowledge (hypotheses 5 and 6, as well as 8a and 9a). Cognitive ability and goal commitment were entered on the first step, metacognitive training and goal type on the second step, and learning activity and metacognitive activity on the third step. This analysis examined the effects of metacognitive and learning activity on knowledge after cognitive ability, metacognitive training, and goal type have been controlled.

Regression four reversed the order of entry for steps two and three above. Thus to test the mediation hypothesis (8a and 9a), one expects any effects of metacognitive training and goal type to diminish when metacognitive activity and learning activity are controlled first.

Regression five tested the hypothesized relation between knowledge and performance (hypothesis 7). The dependent variable was performance. Cognitive ability was entered on the first step, and knowledge on the second step.

Regression six tested later half of the model (hypotheses 8b and 9b). The dependent variable was performance. (Separate regressions will be run for the various performance measures including score, number engaged, decision accuracy, and penalty circle intrusions). Step one of the regression contained cognitive ability and goal commitment. Step two contained metacognitive activity and learning activity. Step three contained knowledge. In this way the effects of knowledge on performance can be demonstrated after controlling for metacognitive training, goal type, metacognitive activity, and learning activity.

Regression seven will analyzed the mediation effects (hypotheses 8b and 9b) by reversing the order of entry such that knowledge was entered first, then learning activity and metacognitive activity, then metacognitive training and goal type. The effects of training, goal type, metacognitive activity, and learning activity should dissipate once knowledge was entered first.

Table 1

Study Hypotheses and Analyses

| Hypothesis | Independent Variables | Dependent Variable | Analyses |
|---|---|---|---|
| 1 | Goal Type (perf. vs. sequenced subgoals) | Learning Activity | #2 hierarchical regression |
| 2 | MC training (yes/no) | MC Activity | #1 hierarchical regression |
| 3 | Goal Type | MC Activity | #1 hierarchical regression |
| 4 | Goal Type x MC training inter. | MC Activity | #1 hierarchical regression |
| 5 | Learning activity | Knowledge | #3 hierarchical regression |
| 6 | MC activity | Knowledge | #3 hierarchical regression |
| 7 | Knowledge | Performance | #5 hierarchical regression |
| 8a | MC activity, Learning activity, MC training, Goal type | Knowledge | #3 & #4 hierarchical regression |
| 8b | MC activity, Learning activity, MC training, Goal type, knowledge | Performance | #6 & #7 hierarchical regression |
| 9a | MC activity, Leaning activity, MC training, Goal type | Knowledge | #3 & #4 hierarchical regression |
| 9b | MC activity, Learning activity, MC training, Goal type, Interaction, Knowledge | Performance | #6 & #7 hierarchical regression |

# RESULTS

## Descriptive Data

Table 2 presents the means, standard deviations, and scale reliabilities for variables across all subjects. The descriptive indices indicate that the subjects reported relatively high goal commitment (mean across all three administrations was 6.52 on an 8-point scale). The scales generally demonstrated sufficient reliability to proceed with further analyses. One reliability which was somewhat low was the knowledge test, which is consistent with the multi-dimensional nature of the test and the one/zero scoring (i.e. correct or incorrect). Principle- axis actor analyses indicated that this scale contained two factors, one comprised of primarily procedural knowledge items and one comprised of primarily declarative knowledge items. Descriptives for these subscales are also provided. These scales and the factor analysis will be discussed in greater detail below.

Subjects, tended to receive fairly low scores (mean = -787) consistent with the difficulty of the task, the high penalty points deducted (mean = 1030), and the fact that the simulation starts them with a negative score as explained in the Individual Instructions located in Appendix C. During the final trial, participants engaged an average of almost 7 targets or about one per minute, with an average of just under five correct decisions.

The intercorrelations among variables can be found in Table 3. These zero-order correlations indicate that many of the dependent performance variables were significantly intercorrelated. These intercorrelations reflect that the degree to which participants made quick, accurate decisions, protected the outer penalty circle, and avoided penalty points largely determine how well they scored consistent with the design of the simulation. Avoiding inner penalty circle intrusions (and the resulting 50 point penalty) did not correlate significantly with score ($r = -.14$). The independent variables also showed some significant intercorrelations. For instance, self-reported metacognitive activity correlated with self-reported learning activity $r = .46$. The goal commitment measure given for the successive goals correlated highly across the times .69-.72. The type of goal (learning or performance) did not correlate significantly with reported commitment at any of the three administrations. Metacognitive training did not correlate significantly with reported metacognitive activity, nor did learning goals correlate significantly with reported learning activity. This is preliminary evidence that the manipulations did not have a strong effect, or had an unintended consequences.

To investigate the scales further, principle components factor analyses were performed on the metacognitive activity scale, the learning activity scale, and the knowledge test. These analyses were performed to investigate whether the scales contained imbedded factors which could be used for finer distinctions regarding type of metacognitive or learning activity, or specific types of knowledge. Separate factor analyses on the metacognitive and learning activities scales did not yield readily interpretable factors, and eigen values suggested one factor. The learning and metacognitive activity scales were therefore left in tact for further analyses. The factor analysis on the knowledge test demonstrated evidence for two factors. Following a scree analysis and investigation of two and three factor solutions, the two factor solution emerged as readily interpretable. Consistent with the way the items were written, the knowledge test yielded factors that could be interpreted as primarily items assessing declarative knowledge and items assessing procedural knowledge. An example of an item from the procedural scale (that is, dealing with "how to" information, usually about prioritizing targets) is, "you have just engaged three targets near your inner penalty circle, which of the following should you do next..."? The declarative knowledge item requires only that the person recall a specific piece of information. The declarative scale included items 2, 4, 6 10 , 11 from the original knowledge scale. An example of an item from the declarative knowledge scale is "A submarine might have which of the following communication times..."? The procedural items generally involve understanding a given situation, and choosing the best option. The procedural knowledge scale was comprised of items 1, 8, 17, 18, 19, 20 from the original knowledge scale. All other items from the original scale either loaded equally on both factors, or low on both, and were omitted from the analyses using the declarative and procedural knowledge scales. The alpha reliabilities of the declarative ($\alpha = .63$) and procedural ($\alpha = .54$) scales are close to, or better than those of the original knowledge test ($\alpha = .58$).

Another issue was potential differential commitment to the learning goal as opposed to the performance goal. To assess differences, an average goal commitment score was computed by averaging the goal commitment score across the three administrations. These averages were then compared using a t-tests to see whether the groups receiving learning goals differed on average from those receiving performance goals. The mean goal commitment average for the performance goal subjects was 6.45, sd = 1.32. The mean for the learning goal subjects was 6.42, sd = 1.20. The difference was not significant ( $p = .904$) indicating that the subjects reported comparable commitment to either type of goal.

Sequenced subgoals and learning activity.

Hypothesis 1 suggested people given subgoals would engage in a significantly greater amount of learning activity than those pursuing performance goals. That is, people given subgoals sequenced to bring them from declarative knowledge acquisition, to procedural knowledge acquisition, and then to scoring were predicted to engage in a significantly greater amount of learning activity than will those perusing performance goals. Initial regression analyses did not support this hypothesis. After controlling for goal commitment and cognitive ability (which constituted a significant effect due primarily to goal commitment), entering goal type did not significantly change the $R^2$ for learning activity as assessed by self-report (see Table 4). A secondary analysis was conducted using a tally of learning activity reported in the post scenario questionnaire. This analysis was conducted because this tally might more accurately reflect the amount of learning activity since they are better able to capture inter-subject (relative) differences. A person may report that he or she did little, when relative to other subjects they did a great deal. In addition, the learning activity questionnaire focuses on different *types* of activity and therefore may not capture the amount of a particular activity. The tally was conducted by the experimenter after covering the condition number and shuffling the post scenario questionnaires to ensure that the experimenter was blind to the condition. The tally and learning activity questionnaire scores correlated only .14 which was not significant ($p > .10$). Typical learning activities were repetition of the cues, trying to determine an underlying logic, devising a system for memorizing the cues, and trying to determine abstract rules underlying the simulation. The regression analysis using this tally as the dependent variable supported Hypothesis 1. After controlling for cognitive ability and goal commitment, goal type significantly impacted the amount of learning activity reported in the post-scenario questionnaire ($\Delta R^2 = .09$, $p = .001$, see Table 5). That is, subjects reported more learning activity on the post scenario questionnaire when they were given sequenced subgoals than when they were given performance goals.

Metacognitive Activity and Training.

Hypothesis 2 suggested that Metacognitive training would be positively related to metacognitive activity performed in support of learning. That is, individuals given metacognitive training would report and demonstrate increased use of metacognitive activity to assess and optimize their learning. Hypothesis 3 suggested that sequenced subgoals would lead to more metacognitive activity in support of learning than performance goals. In addition, Hypothesis 4 suggested that metacognitive training and goal type would interact to determine the amount of metacognitive activity devoted to learning. Those with sequenced learning subgoals were predicted to engage in more metacognitive activity as a result of metacognitive training. These hypothesis were tested in the hierarchical regression depicted in Table 6. The dependent variable was self-reported metacognitive activity from the metacognitive activity scale. After controlling for cognitive ability on step one, step two contained dummy variables for metacognitive training and learning goals, and step three contained their interaction. Neither step added significantly to the variance accounted for in self-reported metacognitive activity. (The $\Delta R^2$ for step two was .002, and .000 for the interaction on step three.) Thus, Hypotheses 2, 3, and 4 were not supported.

To follow up this analysis, two raters blind to the subjects' experimental condition rated the quality of metacognitive activity reported in the post-scenario questionnaires. Raters were asked to evaluate the questionnaires for metacognitive activity on a scale of 1 (lowest) to 5 (highest). Raters met with the experimenter to clarify the definition of metacognitive activity, and then rated discussed 10 questionnaire responses to calibrate their ratings. Then, they rated all of the remaining 100 questionnaires independently. Their ratings correlated .72 significantly ($p < .01$), only twice were disagreements by more than 1 point and never more than 2 points. The ratings were then averaged and this was used as a rating of the *quality* of metacognitive activity reported in the post scenario questionnaires. These ratings were completed to determine if there was beta change in the subjects' self-report. That is, pilot testing indicated that those with metacognitive training may hold themselves to a higher standard when judging their own metacognitive activity. The post-scenario questionnaire was an open ended question regarding how they attempted to meet their goal. The ratings correlated with the self-reported metacognition $r = .25$ ($p < .01$). The same hierarchical regression performed above was repeated to test Hypotheses 2, 3, and 4 using the ratings as the dependent variable.

The analyses were similar to those reported earlier. The only variables that contributed significantly to the metacognitive ratings were the controlled variables, cognitive ability and goal commitment. Neither the learning goals, the metacognitive training, nor the interaction had a significant regression weight. Likewise, the change in $R^2$ was not significant for the second and third steps (see Table 7).

A final analysis was run using a tally of the amount of metacognition as reported in the post scenario questionnaires. This was an attempt to measure the amount of metacognition subjects engaged in during the task -- to quantify the amount of metacognitive activity reported by the subject on the post-scenario questionnaire. The summary measure was conducted in the same manner as the learning activity tally. The experimenter counted the number of times metacognitive activity was indicated by subjects on the post scenario questionnaire. After controlling for cognitive ability, the step containing learning goals and metacognitive training contributed significantly with a change in $R^2 = .08$, due primarily to the metacognitive training ($\beta = .38$, $p < .01$), the regression weight for the goal type was not significant ($\beta = .10$, $p > .05$). The interaction was also not significant. This analysis (outlined in Table 8) indicated some support for Hypothesis 2, that metacognitive training would lead to more metacognitive activity.

Hypothesis 5 suggested that increased learning activity would lead to increased learning in terms of declarative and procedural knowledge. Similarly, Hypothesis 6 suggested that metacognitive activity would be positively related to knowledge. People engaging in more metacognitive activity will demonstrate increased declarative and procedural knowledge. These hypotheses were tested by regressing learning and metacognitive activity onto knowledge as assessed by the declarative and procedural scales of the knowledge test. For these regression analyses, cognitive ability and goal commitment were entered at the first step, metacognitive and learning activity were entered for the second step. All of the different measurement techniques (the scales, ratings, and tallies) were entered on this step since all were measures of the same variables without a strong a priori theory as to which would be the most efficacious technique, thus the regression weights may help to indicate which were the strongest measurement techniques for determining the impact of metacognition on knowledge acquisition. This regression was repeated for the declarative and procedural knowledge subscales as the dependent variable (see Tables 9-10). The results indicated that cognitive ability was related to knowledge, but metacognitive activity and learning activity generally did not add significantly in terms of $\Delta R^2$. It is, perhaps, noteworthy that the ratings of metacognitive activity had the strongest regression weights of the methods of metacognition measurement, approaching significance for the procedural knowledge scale. Overall, however, these analyses did not support Hypotheses 5 or 6.

Knowledge and Performance.

Hypothesis 7 suggested that knowledge would be positively related to skill performance. Individuals demonstrating higher levels of declarative and procedural knowledge were expected to exhibit better performance. Several variables were collected to assess performance. These include the overall score, the number of targets engaged (indicates speed), correct decisions (accuracy of engagements), penalty points assessed, inner penalty circle intrusions, and outer penalty circle intrusions. The analyses were performed by entering goal commitment and cognitive ability on step one, and then declarative and procedural knowledge on step two (see Tables 11 through 15) . The step containing declarative and procedural knowledge was significant for score ($\Delta R^2$ = .17, $\beta_d$=.31, $\beta_p$=.32), correct decisions ($\Delta R^2$ = .16, $\beta_d$=.34, $\beta_p$=.28), and outer penalty circle intrusions ($\Delta R^2$ = .06, $\beta_d$= -.07, $\beta_p$= -.25). Only the regression weight for procedural knowledge was significant in the regression for outer penalty circle intrusions. For the number engaged, the change in $R^2$ was not significant for the knowledge step (p = .13), but the regression weight for declarative knowledge approached significance (p = .07). Similarly, for penalty points -- the change in $R^2$ was not significant (p = .14), but the procedural knowledge regression weight approached significance (p = .06). For inner penalty circle intrusions, neither the change in $R^2$, nor the regression weight even approached significance. Overall, these analyses support Hypothesis 7, that declarative and procedural knowledge are related to higher performance.

Tests for Mediation.

Hypothesis 8a suggested that the effects of metacognitive training on knowledge acquisition would be fully mediated by the impact of this training on metacognitive activity. Metacognitive training was not expected to exhibit direct effects on knowledge acquisition. To examine mediation, one must demonstrate relationships from the first variable to the second (a to b), from the second to the third (b to c), and the relationship between the first and third (a to c) must diminish when the second is paritalled out first. There is limited evidence that the first variable (metacognitive training) impacted the second (metacognitive activity). The training did impact the amount of metacognition reported in the post-scenario questionnaire (indicated by the tally of such statements), and so there is some evidence of the "a to b" link. However, metacognitive activity did not impact the declarative or procedural knowledge scores, so the "b to c" link is missing. Therefore, there can be no test for mediation, and Hypothesis 8a is not supported. (The regressions demonstrating this are located in Appendix M).

Hypothesis 8b suggested that the effects of metacognitive training on skill performance will be fully mediated through effects of this training on metacognitive activity, and metacognitive activity on knowledge development or performance. As before, this hypothesis was tested by hierarchical regression on the performance variables, then reversing the order of entry. In general, the mediational hypotheses received only mixed support. Knowledge tended to have the strongest effect, regardless of the order of entry. However, for penalty points and number of targets engaged the effect of knowledge did dissipate when metacognitive activity and training were entered first (see Tables 17 and 18). However, the effects for metacognitive training and activity themselves did not appear to influence the dependent variables in the these cases, meaning there is a lack of the "b to c" linkage as well as the aforementioned "a to b" linkages. Therefore, there can be no test for mediation, and Hypothesis 8b is not supported. (The regressions demonstrating this are located in Appendix N.)

Hypothesis 9a suggested that the effects of goal type on knowledge acquisition would be mediated by the effect of goal type on the learning and metacognitive activity. Goal type was not expected to exhibit direct effects on knowledge acquisition. As above, this hypothesis was tested using hierarchical regression with reversal of order to determine if there were effects of learning goals on performance, and if this relationship diminished when learning activity is added first . However, the relationship between goal type and declarative and procedural knowledge were not significant after controlling for cognitive ability and goal commitment. Therefore, there was no relationship to mediate. The regression weights for learning activity tended to be negative as well. These results do not support hypothesis 9a. (Nevertheless, the regression analyses can be found in Appendix O.)

Hypothesis 9b, stated that the effects of goal type on skill performance would be fully mediated through effects of goal type on learning activity, metacognitive activity, their effects on knowledge development. Goal type was not expected to exhibit a direct effect on knowledge acquisition or performance. These hypotheses were tested as above, using hierarchical regression, and reversal in the order of entry. As above, however, there was limited evidence to support the necessary linkages, in particular there was little evidence that goal type had an effect on performance variables to be mediated. Overall, only knowledge had consistent effects across performance variables, and these effects were not mediated substantially by learning activities or goal type. For example knowledge accounted for significant variance in score, correct decisions, and outer penalty circle intrusions (procedural). These effects were maintained regardless of order of entry. The metacognitive measures showed some significant regression weights, but did not impact variance accounted for significantly. Of these significant regression weights, two were for metacognitive activity measured by tallying up metacognitive statements in the post scenario questionnaire, but these were negative weights. That is, metacognitive activity was negatively related to targets engaged and correct decisions made. Hypothesis 9b was therefore not supported. (Analyses are located in Appendix P.)

Table 2

Means, SDs, and Reliabilities of Study Variables

| VARIABLE | # ITEMS | MEAN | SD | α |
|---|---|---|---|---|
| Metacognitive Activity Score | 13 | 4.42 | .88 | .72 |
| Metacognitive Activity Rating | 2* | 2.37 | .82 | -- |
| Metacognitive Activity Tally | -- | 1.64 | 1.46 | -- |
| Learning Activity Score | 17 | 3.69 | .80 | .81 |
| Learning Activity Tally | -- | .89 | .89 | -- |
| Goal Commitment 1 | 3 | 6.45 | 1.24 | .96 |
| Goal Commitment 2 | 3 | 6.37 | 1.33 | .97 |
| Goal Commitment 3 | 3 | 6.77 | 1.31 | .98 |
| Knowledge Test | 20 | 11.92 | 2.78 | .58 |
| Procedural | 6 | 4.66 | 1.30 | .54 |
| Declarative | 6 | 2.54 | 1.62 | .63 |
| Score | -- | -787 | 374 | -- |
| Targets Engaged | -- | 6.97 | 2.60 | -- |
| Correct Decisions | -- | 4.70 | 2.32 | -- |
| Penalty Points (deducted) | -- | 1030 | 95 | -- |
| Outer PC Intrusions | -- | 9.42 | .88 | -- |
| Inner PC Intrusions | -- | 1.75 | .79 | -- |

*number of raters

Table 3

Intercorrelations Among Study Variables

| VARIABLE | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Score | – | | | | | | | | | | |
| 2. Number Engaged | .28* | – | | | | | | | | | |
| 3. Correct Decisions | .86* | .71* | – | | | | | | | | |
| 4. Penalty Points | -.51* | -.38* | -.43* | – | | | | | | | |
| 5. Outer PC Intrusions | -.48* | -.26* | -.35* | -.98* | – | | | | | | |
| 6. Inner PC Intrusions | -.14 | -.34* | -.23* | .36* | -.06 | – | | | | | |
| 7. Learning Activity[b] | .04 | .01 | .02 | -.08 | -.05 | -.08 | – | | | | |
| 8. MC Activity[b] | .17 | .13 | .16 | -.23* | -.16 | -.19* | .46* | – | | | |
| 9. Goal Comm. 1 | .20* | .21* | .25* | -.12 | -.15 | .05 | .31* | .41* | – | | |
| 10. Goal Comm. 2 | .20* | .22* | .26* | -.10 | -.13 | .04 | .32* | .42* | .72* | – | |
| 11. Goal Comm. 3 | .09 | .07 | .11 | -.05 | -.10 | .10 | .32 | .37* | .69* | .72* | – |
| 12. Learning Goal[a] | -.15 | .11 | -.04 | .06 | .08 | -.02 | .09 | -.02 | .02 | -.02 | .14 |
| 13. MC Training[a] | -.15 | -.15 | -.19 | .01 | .04 | .16 | .01 | -.06 | -.02 | .04 | .04 |
| 14. Knowledge Test | .42* | .27* | .43* | -.29* | -.33* | .04 | .04 | .19* | .24* | .17 | .11 |
| 15. Declarative | .34* | .22* | .37* | -.13 | -.12 | -.04 | .07 | .11 | .18 | .16 | .10 |
| 16. Procedural | .29* | .15 | .27* | -.22* | -.28* | .11 | .02 | .11 | .19* | .10 | .07 |
| 17. MC Ratings | .26* | .12 | .25* | -.11 | -.09 | -.06 | .19* | .25* | .29* | .26* | .18 |
| 18. MC Tally | .02 | -.11 | -.07 | -.14 | -.14 | -.03 | .11 | .16 | .10 | .17 | .15 |
| 19. Learning Tally | -.02 | .04 | .02 | .07 | .07 | .02 | .14 | .02 | -.08 | -.01 | .03 |

n=106, * $p < .05$, a=coded, 1= learning goal/MC Training; 0 = perf. goal/no MC Training, b=self-report score

Table 3 (Cont'd)

Intercorrelations Among Study Variables

| VARIABLE | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|---|---|---|---|---|---|---|---|---|
| 12. Learning Goals[a] | – | | | | | | | |
| 13. MC Training[a] | .03 | – | | | | | | |
| 14. Knowledge Test | -.02 | -.06 | – | | | | | |
| 15. Declarative | .10 | -.13 | .62* | – | | | | |
| 16. Procedural | -.11 | -.03 | .66* | .07 | – | | | |
| 17. MC Ratings | .02 | -.12 | .30* | .16 | .26* | – | | |
| 18. MC Tally | .01 | .26* | .12 | -.01 | .08 | .47* | – | |
| 19. Learning Tally | .21* | -.09 | -.11 | -.11 | -.09 | .13 | .11 | – |

n=106, * $p < .05$, a=coded, 1= learning goal/MC Training; 0 = perf. goal/no MC Training, b=self-report score

Table 4

Hierarchical Regression Results of the Test of Hypothesis 1– Impact of Goal Type on Learning Activity as indicated by the Learning Activity Questionnaire

| VARIABLE | $\beta$ | $\Delta R^2$ | $R^2$ |
|---|---|---|---|
| STEP 1: | | | |
| Goal Commitment | .36** | .13 | .13** |
| Cognitive Ability | -.04 | | |
| STEP 2: | | | |
| Goal Type | .07 | .01 | .14** |

*p<.05, **p<.01
n = 106

Table 5

Hierarchical Regression Results of the Test of Hypothesis 1-- Impact of Goal Type on Learning Activity as indicated by the Post Scenario Questionnaire

| VARIABLE | β | $\Delta R^2$ | $R^2$ |
|---|---|---|---|
| STEP 1: | | | |
| Goal Commitment | -.01 | .004 | .00 |
| Cognitive Ability | -.06 | | |
| STEP 2: | | | |
| Goal Type | .30 | .09** | .09* |

*p<.05, **p<.01
n = 106

Table 6

Hierarchical Regression Results of the Test of Hypotheses 2, 3, and 4 -- Impact of Metacognitive Training, Learning Goals and their Interaction on Self Reported Metacognitive Activity

| VARIABLE | β | $\Delta R^2$ | $R^2$ |
|---|---|---|---|
| STEP 1: | | | |
| Cognitive Ability | -.02 | .202** | .20** |
| Goal Commitment | .45 | | |
| STEP 2: | | | |
| M.C. Training | -.07 | .006 | .21** |
| Goal Type | -.04 | | |
| STEP 3: | | | |
| M.C. Training X Goal Type | .00 | .000 | .21** |

*$p<.05$, **$p<.01$
n = 106

Table 7

Hierarchical Regression Results of the Test of Hypotheses 2, 3, and 4 -- Impact of Metacognitive Training, Learning Goals and their Interaction on Rated Metacognitive Activity

| VARIABLE | $\beta$ | $\Delta R^2$ | $R^2$ |
|---|---|---|---|
| STEP 1: | | | |
| Cognitive Ability | .21** | .12** | .12** |
| Goal Commitment | .23** | | |
| STEP 2: | | | |
| M.C. Training | -.08 | .010 | .13** |
| Goal Type | .03 | | |
| STEP 3: | | | |
| M.C. Training X Goal Type | -.04 | .000 | .13** |

*p<.05, **p<.01
n = 106

Table 8

Hierarchical Regression Results of the Test of Hypotheses 2, 3, and 4 -- Impact of Metacognitive Training, Learning Goals and their Interaction on the Tally of Metacognitive Activity

| VARIABLE | β | $\Delta R^2$ | $R^2$ |
|---|---|---|---|
| STEP 1: | | | |
| Cognitive Ability | .12 | .030 | .03 |
| Goal Commitment | .12 | | |
| STEP 2: | | | |
| M.C. Training | .38** | .07* | .10* |
| Learning Goals | .00 | | |
| STEP 3: | | | |
| M.C. Training X Learning Goal | -.18 | .01 | .11* |

*p<.05, **p<.01
n = 106

Table 9

Hierarchical Regression Results of the Test of Hypotheses 5 and 6 – Impact of Learning and Metacognitive Activity on Declarative Knowledge

| VARIABLE | β | $\Delta R^2$ | $R^2$ |
|---|---|---|---|
| STEP 1: | | | |
| Cognitive Ability | .29** | .121** | .12** |
| Goal Commitment | .06 | | |
| STEP 2: | | | |
| Learning Activity (tally) | -.09 | .021 | .14** |
| M.C. Activity (tally) | -.10 | | |
| Learning Activity (score) | .02 | | |
| M.C. Activity (ratings) | .11 | | |
| M.C. Activity (score) | .04 | | |

*p<.05, **p<.01
n = 106

Table 10

Hierarchical Regression Results of the Test of Hypotheses 5 and 6 -- Impact of Learning and Metacognitive Activity on Procedural Knowledge

| VARIABLE | β | $\Delta R^2$ | $R^2$ |
|---|---|---|---|
| STEP 1: | | | |
| Cognitive Ability | .29** | .121** | .14** |
| Goal Commitment | .06 | | |
| STEP 2: | | | |
| Learning Activity (tally) | -.09 | .021 | .18** |
| M.C. Activity (tally) | -.10 | | |
| Learning Activity (score) | .02 | | |
| M.C. Activity (ratings) | .11 | | |
| M.C. Activity (score) | .04 | | |

*p<.05, **p<.01

Table 11

Hierarchical Regression Results of the Test of Hypotheses 7 – Impact of Declarative and Procedural Knowledge on Score

| VARIABLE | β | $\Delta R^2$ | $R^2$ |
|---|---|---|---|
| STEP 1: | | | |
| Cognitive Ability | -.03 | .064* | .06* |
| Goal Commitment | .08 | | |
| STEP 2: | | | |
| Declarative | .31** | .166** | .23** |
| Procedural | .32** | | |

*p<.05, **p<.01
n = 106

Table 12

Hierarchical Regression Results of the Test of Hypotheses 7 – Impact of Declarative and Procedural Knowledge Number of Targets Engaged

| VARIABLE | β | $\Delta R^2$ | $R^2$ |
|---|---|---|---|
| STEP 1: | | | |
| Cognitive Ability | -.03 | .042 | .04 |
| Goal Commitment | .08 | | |
| STEP 2: | | | |
| Declarative | .11 | .037 | .08 |
| Procedural | .18 | | |

*p<.05, **p<.01
n = 106

Table 13

Hierarchical Regression Results of the Test of Hypotheses 7 -- Impact of Declarative and Procedural Knowledge on the Number of Correct Decisions Made

| VARIABLE | $\beta$ | $\Delta R^2$ | $R^2$ |
|---|---|---|---|
| STEP 1: | | | |
| Cognitive Ability | -.03 | .081 | .08 |
| Goal Commitment | .13 | | |
| STEP 2: | | | |
| Declarative | .34** | .157** | .23** |
| Procedural | .28** | | |

*p<.05, **p<.01
n = 106

Table 14

Hierarchical Regression Results of the Test of Hypotheses 7 – Impact of Declarative and Procedural Knowledge on the Number of Penalty Points Deducted

| VARIABLE | $\beta$ | $\Delta R^2$ | $R^2$ |
|---|---|---|---|
| STEP 1: | | | |
| Cognitive Ability | -.05 | .034 | .03 |
| Goal Commitment | -.04 | | |
| STEP 2: | | | |
| Declarative | -.09 | .037 | .07 |
| Procedural | -.19 | | |

*p<.05, **p<.01
n = 106

Table 15

Hierarchical Regression Results of the Test of Hypotheses 7 – Impact of Declarative and Procedural Knowledge on the Number of Outer Penalty Circle Intrusions Allowed

| VARIABLE | β | $\Delta R^2$ | $R^2$ |
|---|---|---|---|
| STEP 1: | | | |
| Cognitive Ability | -.06 | .046 | .05 |
| Goal Commitment | -.07 | | |
| STEP 2: | | | |
| Declarative | -.07 | .06* | .11* |
| Procedural | -.25** | | |

*p<.05, **p<.01
n = 106

Table 16

Hierarchical Regression Results of the Test of Hypotheses 7 -- Impact of Declarative and Procedural Knowledge on the Number of Inner Penalty Circle Intrusions Allowed

| VARIABLE | β | $\Delta R^2$ | $R^2$ |
|---|---|---|---|
| STEP 1: | | | |
| Cognitive Ability | .01 | .006 | .01 |
| Goal Commitment | .07 | | |
| STEP 2: | | | |
| Declarative | -.06 | .015 | .021 |
| Procedural | .12 | | |

*p<.05, **p<.01
n = 106

Table 17

Hierarchical Regression Results of the Test of Hypotheses 8b -- The mediation of the effects of Metacognitive Training and Activity on Number Engaged Through Knowledge

| VARIABLE | β | $\Delta R^2$ | $R^2$ |
|---|---|---|---|
| <u>EQUATION 1</u> | | | |
| STEP 1: | | | |
| Cognitive Ability | .00 | .042 | .04 |
| Goal Commitment | .12 | | |
| STEP 2: | | | |
| Declarative | .16** | .037 | .08 |
| Procedural | .09** | | |
| STEP 3: | | | |
| M.C. Activity (tally) | -.17 | .034 | .11 |
| M.C. Activity (score) | .04 | | |
| M.C. Activity (rating) | .10 | | |
| STEP 4: | | | |
| M.C. Training | -.07 | .005 | .12 |
| <u>EQUATION 2</u> | | | |
| STEP 1: | | | |
| Cognitive Ability | .00 | .042 | .04 |
| Goal Commitment | .12 | | |
| STEP 2: | | | |
| M.C. Training | -.08 | .021 | .06* |
| STEP 3: | | | |
| M.C. Activity (tally) | -.18 | .029 | .09* |
| M.C. Activity (score) | .04 | | |
| M.C. Activity (rating) | .10 | | |
| STEP 4: | | | |
| Declarative | .16 | .026 | .12 |
| Procedural | .09 | | |

*p<.05, **p<.01
n = 106

Table 18

Hierarchical Regression Results of the Test of Hypotheses 8b – The mediation of the effects of Metacognitive Training and Activity on Penalty Points Through Knowledge

| VARIABLE | β | $\Delta R^2$ | $R^2$ |
|---|---|---|---|
| EQUATION 1 | | | |
| STEP 1: | | | |
| Cognitive Ability | -.05 | .030 | .03 |
| Goal Commitment | .05 | | |
| STEP 2: | | | |
| Declarative | -.09** | .037 | .04 |
| Procedural | -.19 | | |
| STEP 3: | | | |
| M.C. Activity (tally) | -.18 | .053 | .12 |
| M.C. Activity (score) | -.21 | | |
| M.C. Activity (rating) | .11 | | |
| STEP 4: | | | |
| M.C. Training | -.13 | .014 | .13 |
| EQUATION 2 | | | |
| STEP 1: | | | |
| Cognitive Ability | -.05 | .034 | .03 |
| Goal Commitment | .05 | | |
| STEP 2: | | | |
| M.C. Training | .13 | .008 | .04 |
| STEP 3: | | | |
| M.C. Activity (tally) | -.18 | .061 | .100 |
| M.C. Activity (score) | -.20 | | |
| M.C. Activity (rating) | .11 | | |
| STEP 4: | | | |
| Declarative | -.08 | .034 | .13 |
| Procedural | -.19 | | |

*$p<.05$, **$p<.01$
n = 106

# DISCUSSION

This study attempted to create an efficient method of training using the implications of the Kanfer and Ackerman (1989) limited resource model of skill acquisition. A framework was developed, hypotheses proposed, and this model was tested using a complex radar simulation task. The hypotheses and theory suggested that since learners' resources are primarily devoted to learning declarative information early in skill acquisition, and procedural information at an intermediate stage, more efficient learning could result from setting learning goals to direct resources to learning activity. This learning activity would help accomplish to the "subtasks" of attaining declarative and procedural knowledge. Likewise, it was proposed that the metacognitive processes which guide the devotion of resources and use of strategy could be improved with training leading to more effective use of resources, better learning of declarative and procedural knowledge, better strategy selection, and ultimately performance. Results generally did not support the model. Instead, it appeared that cognitive ability (an indicator of trait resources the learner brings to bear) related to knowledge acquisition, and knowledge acquisition related to better performance. The manipulations of goal type and metacognitive training had little effect on the amount or quality of the learning activity and metacognition performed by the subjects after controlling for the effects of goal commitment and cognitive ability. In addition, the amount of learning activity and metacognitive activity had limited effects on the acquisition of knowledge and subsequent performance.

Metacognition

One of the major manipulations of this study was the attempt to train metacognition, a critical support function to knowledge acquisition and performance. However, this manipulation was not successful at increasing the amount or quality of metacognition as measured in three separate ways. The training used had been subjected to two pilot tests and iteratively strengthened prior to this study, but was *still* generally unsuccessful at increasing or improving metacognition. One reason this manipulation may have failed was that metacognition is a skill developed over a lifetime of learning, and is too difficult to train in one short, intense session. Past studies that have been more successful at improving metacognition have tended to occur in educational settings, and have been long in both duration (sessions over time) and study time. In comparison, the current study attempted to train metacognition in one intense "massed" session prior to engaging the task. Given that metacognition is a skill, research has demonstrated that skills are learned better in spaced practice than massed.

In addition, the present study was handicapped by the necessity of making sure the metacognitive training group got no extra time on task, information about the task, or exposure to task information. To meet these conditions, the training was performed on material similar to, but not the same as, the actual information used on the task. This indirect training may have decreased transfer to some extent. Moreover, the evidence in this study suggests that training metacognition in one intense session may not be the most efficacious way to change metacognition when a long time period is not available to devote to metacognitive training.

Metacognitive activity was not found to be particularly effective at explaining variance in knowledge acquisition or performance. Three methods were used to try and capture metacognition. One method, ratings, seemed to be more efficacious in capturing the aspects of metacognition which does improve learning and performance. The three methods did correlate with one another ($r = .25$, $r = .16$, $r = .47$), with the highest correlation being between the tally of metacognition from the post-scenario questionnaire and the ratings of the metacognition in the post-scenario questionnaire. This is logical in that someone who did very little metacognition likely did not do enough to merit high ratings. The regression weights for the different methods indicate that of the three types of measurement, the ratings by independent raters showed the most promise in capturing metacognition that improves learning and performance. The self-report and tally methods captured primarily the *amount* of metacognition -- either how much of each metacognitive activity from the metacognitive questionnaire or how much overall from the tally. The ratings, on the other hand, may have been less deficient in that they were focused on capturing the *quality* of metacognition, not merely the amount. That is, a person could have said "I am learning the cues better" several times on the post-scenario questionnaire (as some subjects did) which boosts the metacognitive tally and indeed reflects an assessment of learning which would show up in a self-report. However, it is not particularly diagnostic or learning, nor helpful for strategy formation. Good metacognition involves accurate self-awareness, diagnosis, and prescription of a good remedy to the problems one is having. This appears to have been captured better in the ratings than other measurement techniques. The regression weights for the ratings were typically high and in the predicted direction relative to other metacognitive measurement techniques on several measured criteria (e.g. declarative knowledge, procedural knowledge, score, number engaged, correct decisions). The other methods sometimes had high relative weights, but often in the opposite direction as predicted (e.g. correct decisions and number engaged). This may be an indicator that the quality and not the amount of metacognitive activity is a better way to operationalize metacognitive activity. This may be especially true for an experimental setting where amount may more readily indicate demand effects than quality measures. That is, subjects may pay more "lip service" to metacognitive activities due to the training, but it is the quality of the activities that demonstrates the state of the person's metacognition and will improve learning and performance. Quality ratings appear to hold the most promise as a measurement technique at assessing the aspect of metacognition that will be beneficial to performance.

Learning Goals

The learning goals related to learning activity in the tally of statements from the post-scenario questionnaire, but not the learning activity questionnaire itself. This seems to indicate that although the learning goal group did focus on learning as an end in itself, they did not adopt a strategy that was different than the behavior the performance goal group was doing by default. This may be a function of the task.

The task involves learning cue values and prioritizing targets to prevent them from entering penalty zones. Although many possible learning strategies exist, and learning goal subjects were told not to focus on their score (and even had the score feedback turned off), the most obvious way to learn the cues and the game was simply to go through the targets. The researchers had anticipated that subjects would exercise the option of spending extra time studying the materials, creating mnemonics, visualizing, relating information, or using other strategies in combination. However, the task with its repetitious nature seems to inspire a repetition strategy. Most people, regardless of goal condition, learned the cues by going through the targets and looking at the review sheet less and less. Even if this was not the most efficient strategy, it was the strategy virtually all subjects adopted. So it would appear that the repetition strategy adopted by the learning goal group was the same behavior engaged in by the performance goal subjects. Thus, they did not change much or benefit especially from the learning goal manipulation and looking at learning as an end in itself early in the task.

The procedural manipulation also did not have much impact on learning activity or performance. This was a first attempt at developing a procedural learning goal which could both adhere to the definition of procedural knowledge, remain specific, and be understood by the subjects. Subjects in the learning goal condition were encouraged to use the task to develop good answers to complete the second half of "if/then" statements which were an attempt to capture the if-then nature of procedural knowledge. Prioritizing targets was one of the most important task functions using procedural knowledge. Most subjects did very little in terms of learning activity, hypothesis testing, purposeful exploration, or other means of learning procedural knowledge (other than repetition) to respond to the situations described in the "if" statement they were given. They seemed to simply repeat task instructions rather than thinking deeply about the nature of the task. Or, they may have been thinking about the task, but without having internalized enough of the declarative knowledge to lead to effective procedures (i.e. the procedural manipulation came too soon). The rules they generated were often poor strategically. For instance, many indicated that they would guard the inner penalty circle more than the outer circle, even though the inner circle was worth fewer points. As with the metacognitive activity, simply devoting attention to procedures does not improve one's learning automatically. Rather, there has to be quality resources devoted, and some logical thought used based on accurate knowledge.

Neither learning activity nor metacognition related to substantially better learning or performance. One possibility for both learning and metacognitive activity is that learning and performance were improved, but were not captured due to the timing of measurement. This study was concerned with end of training performance and looked at performance only at the end of almost 50 minutes of task exposure. It may be that people who engaged in theses behaviors learned the information faster (i.e. by the second or third trial) but not better. Eventually, by the end of the fifth trial when the knowledge test was presented, the other subjects may have caught up. Likewise, performance may have had some initial improvements, but by the sixth and final trial (during which performance measures were collected) any initial margins had diminished. An examination of the performance mapped over time could demonstrate any initial gains.

Of course while measuring too late might be one problem, another timing problem could have been that the subjects with learning goals needed more time. In the short run, the goals may have made little difference, but given longer time on task, with more spacing between learning goals, they may have been more effective. Other researchers (Kanfer and Ackerman for example) are able to have subjects work on the task for many more hours than subjects in the present study. It may be that the learning goals moved too quickly to the procedural stage, when really the goals would have been more beneficial if spaced better. That is, subjects may have needed more time before they were ready to move on to procedualization issues. A longer assessment using repeated measures would be necessary to detect such phenomena.

Knowledge

Knowledge was one of the most powerful predictors of performance in the model. The pattern of correlations indicates that declarative knowledge was more related to speed/accuracy aspects of performance, and procedural knowledge was more related to strategic aspects of performance like prioritization. For example, correlations between declarative knowledge and the number of targets engaged is significant, but procedural knowledge and number engaged was not significant. On the other hand, procedural knowledge related significantly to penalty points and outer penalty circle intrusions (indicators of prioritization) whereas declarative knowledge did not. Similar patters were demonstrated in the regressions. The regression weights for declarative knowledge are higher than those for procedural knowledge for number of targets engaged and correct decisions (speed and accuracy indicators). Meanwhile, the regression weight for procedural, but not declarative knowledge is significant in predicting outer penalty circle intrusions which reflect the prioritization of the targets. Both correlate significantly and have significant regression weights with score, consistent with the task design in that both speed, accuracy, and strategic prioritization were important to performance.

Theoretical Considerations

This discussion has centered around the possibility that the results of this study may have been a function of limitations in the methodology. Another alternative is that the theoretical foundations upon which the present model was built are problematic. The results obtained can be construed as consistent with the limited resource model in that this model predicts that early in skill aquisition, self-regulation will only be beneficial if it results in a net increase in resoucres. That is, if the self-regulation somehow frees more resources than it consumes. One can thus say that the current results mean that metacognition was not particulary powerful at increasing knowledge and performance because it did not yield a net increase in on-task resources. However, this leads to question of how one can know whether one has caused a net increase in resources? How can one measure the net resource gains and losses? It is rather circular to suggest that any regulation which leads to better performance increased net resources, and any which lead to worse performance decreased net resources. A performance increase may be caused by self-regulation which decreases net resources but yields a better strategy for using the fewer resources which remain. Likewise, poorer performance might be the result of self-regulation which increases net resources, but decreses the efficacy of the way they are used. Again, the limited resources model suggests that a mere increase of resources leads to an increase in performance. This is not always the case. The way in which these resources are used may be a key to performance variance -- two people both high in resources could demonstrate very different performance on the task used for this study using different strategies.

This highlights another problematic distinction for Kanfer and Ackerman. They distinguish between on-task and off-task resources. Although some uses of resources can reasonably be considered off-task (e.g. thinking about lunch instead of the task), other activities are considered off-task by Kanfer and Ackerman which may be very important to the long term success of the task. One may find that self-regulatory thought early in skill acquisition is detrimental to performance at that time, but this regulation may expedite increases in performance over time. Using the first trial test out strategies is a poor use of resources in terms of first trial success, but it is critical to success in other trials. Is this self-regulatory thought then considered off-task even though it is about the task and leads to better performance? The failure to discuss what the criteria are for an activity to be considered on-task or off-task, mixed with the failure to distinguish learning from performance gives one little guidance about what activities to encourage for those aquiring a skill.

Another, perhaps more fundamental, theoretical consideration is whether self-regulation is resources consumptive. The Kanfer and Ackerman model posits that proximal motivation (i.e. self-regulation) is resources consumptive which is the critical assumption for explaining performance decrements due to competing resources. However, other reseachers suggest that self-regulation is an automatic process and requires little, if any, resources. Lord and Levy (1994) suggest that monitoring performance to detect goal discrepancies (or what Kanfer and Ackerman call self-monitoring and self-evaluation) is data driven and automatic. Similarly, Bargh (1989) reviewed the empirical liturature which demonstrated that situational scripts and complex action squences (general memory structures) automatically guide attention and behavior when working toward a conscious goal. Since these scripts are generalizeable across problems, they are applied repeatedly, flexibly, and automatically to new situations. This reseach would suggest that self-regulation effects performance not by increasing or decreasing resources devoted to the task, but by altering the behaviors and strategies selecting those which are more effective at reducing goal discrepancies. Thus, those who employ more effective automatic processes will choose better strategies than those with poorer self-regulation.

The findings in the current study are consistent with the notion of automatic regulation. Participants may have (and in fact appeared to have) applied learning techniques which were familiar, whether or not they were effective and regardless of a manipulation urging them to actively consider and evaluate their strategy. They may have been guided by the kind of automatic process Bargh considers. This is especially true for adult college students such as the participants in this study. Many years of school has likely created strong scripts and action sequences to guide their learning behavior with little conscious thought. It may be that given a particular type of learning task, a particular script formed over many years is activated. For example, given a task requiring memorization, participants would automatically begin using a rehersal strategy which is familiar,one they have used in the past. This may take place with little conscious consideration of the strategy employed, or possible alternative strategies which may be more effective.

If in fact self-regulation is to some exent automatic, then one would expect that a one time manipulation aimed at consciously changing regulation would have limited succes. It may not work at all if people engage in these processes automatically since they will have diffiulty breaking out of the routines. Like changing the way someone walks. Or, if they do attempt to stop the automatic routines, instead of saving resources, they will potentially use more by having tocontrol a process which otherwise takes place automatically. Likewise, one would expect people to have limited insight into their own self-regulatory processes limiting the predictive ability of self-report measures of self-regulation. Automatic processes, particularly those which are totally unconscious or have reached automaticity are difficult for people to articulate and describe. Again, this is consistent with the current findings that self-report measures of self-reguation (in this case metacognition) did not demonstrate much predictive efficacy. People may have had difficulty describing processes which were automatic.

The literature on self-regulation, and metacognition in particular, is frought with problems both methodological and theoretical. Failure to control for important and better understood factors (such as ability, or motivation in forms such as goal committment) may lead to an overestimation of the efficacy of self-regulatory manipulation like training. Also, the lack of theoretical specificity about the exact mechanisms of self-regulation which are being assessed, measured, manipulated, and considered has lead to contradictory findings. More work is needed in this liturature to establish effective guidelines for research in this area, and to develop our theoretical clarity and understanding of self-regulatory constructs.

Implications and Future Directions

The present study attempted to address some of the implications an limitations of the limited resources model of skill acquisition. The limited resources model has tended to be descriptive, not prescriptive, to maintain a limited view of learning and performance, and has not addressed what learners do with their resources that yields learning.

To address the first problem, manipulations were used which appeared consistent with the limited resources model. The limited resource model suggests that self-regulation will improve performance if the benefits of metacognition outweigh the costs in resources. This means that to be beneficial in early skill acquisition, metacognition must be efficient and effective. This notion is consistent with the findings that the quality, and not merely the quantity of metacognition appears to relate to learning and performance. Presently, an intense training session was not successful in bringing about improvements in the quality of metacognition. It may be

that only longer periods of training, or training on different aspects of metacognition, might be successful at improving the quality and efficiency of metacognition such that sufficient resources are saved to benefit performance.

Nevertheless, the current findings suggest that a more efficacious technique for generating increased metacognition or higher quality metacognition may be to invoke a direct manipulation. This would involve forcing the learners to perform metacognition on-line as they learn. Metacognitive questions would be written directly into the task training itself. For example, questions may be imbedded in the material, or trainers may ask questions such as, "How effective is your current strategy? How do you know if it is working?" This method eliminates the transfer problems of the metacognitive training, and people may learn the important questions to ask themselves with repeated exposure to such an intervention. However, this method would require trainers to consider the important metacognitive questions at each learning stage, and then write them into the training and leave sufficient time for learners to consider these issues. Or, the trainer may need to be present to help guide the metacognitive processes (a more "directed learning" approach). For some, even asking the correct questions may not be sufficient since they cannot generate realistic answers, they may need an external guide to help them evaluate their own answers.

There was some evidence of this type of metacognitive failure in the post-scenario questionnaires when people evaluated their strategies incorrectly, adopting a strategy that was based on incorrect information or a poor evaluation of their own task comprehension. It has been said that a wise man knows what he does not know.

People with poor metacognitive skills, they may not know what they do not know even if they are asked to think about it. Research is needed to determine whether metacognitive manipulations are in fact a more efficacious and efficient way to improve metacognition for skill acquisition. Moreover, we must learn how much guidance is needed to enable people with varying levels of metacognitive skill to effectively use such an intervention.

Research is also needed to address the fundamental question of the limited resources model of skill acquisition: whether self-regulation and/or metacognition are automatic processes. First and foremost, greater theoretical development is needed around the constrcuts of self-regulation and metacognition. A start would be mapping the specific activities of self-regulation onto the specific acticities that are metacognitive. Where they overlap, and where they are separate. Then, each specific process or activity must be understood individually as to whether they are resource consumptive, and therefore whether attempting to train or manipulate them is a viable alternative. If they are automatic processes, then manipulating them in order to increase resources is not a viable avenue of research. They are not using enough resources to cause a deficit in performance. Attempting to manipulate them therefore will cause a problem because making automatic processes more controlled will necessarily create resource decrements. Research is then needed to address the question of how to manipulate automated processes such that the strategies selected automatically are better strategies for the task at hand. This may mean making people aware of their processes, improving them, and then re-automatizing.

In order to address the second shortcoming of the limited resource model, a limited view of learning and performance, the current study examined declarative and procedural knowledge acquisition in addition to performance oriented measures like score. Learning declarative and procedural knowledge is the primary task in early skill acquisition. Rather than a by product of performance, declarative and procedural knowledge play crucial roles in determining performance. The current findings suggested that declarative and procedural knowledge may impact different aspects of performance. Research is needed which will examine the possibility that declarative and procedural knowledge play different roles in performance, and how this finding, if replicated, may aid in the diagnosing problems and prescribing learning activities to remedy the problem. Recognizing that declarative and procedural learning were critical, the current study attempted to make this learning more efficient using sequenced goals aimed specifically at declarative and procedural knowledge acquisition as instructional design theorists (i.e. Gagne) suggest. Particularly difficult to develop and use were procedural goals. The goal manipulation did not seem to be able to increase procedural knowledge or activities aimed at increasing this knowledge. Both the form and timing of procedural learning goals bears further examination. In addition, research is needed that investigates the types of learning activity that leads to procedural knowledge (if in fact it is more than repetition), and how to help learners use these activities.

The final shortcoming this research addressed was an absence of explanation of what learners do with resources devoted to skill acquisition in order to learn. The limited resource model equates (for resource dependent tasks) the devotion of resources with improved performance. However, people devote resources to particular activities which lead to learning. These activities were divided into metacognitive and more direct learning activities in the current framework. It appeared that doing *more* of these activities does not lead necessarily to improvements in performance. The quality, not quantity, of learning activity may be the key factor in effective learning and performance. In this way, the devotion of resources alone is not sufficient to improve learning. Rather, the activities to which resources are devoted is critical. Cognitive psychology may be helpful in discovering what activities lead to maximal learning. For example, two activities like imaging and repetition may both require a great deal of resources, but if imaging results in more retrieval cues or more efficient "chunking" of the information, it would be expected to be a more effective use of those resources. Theoretically driven research testing the effectiveness of different learning activities is needed. In the current study, few learners explored different types of learning activities. Participants appeared to use strategies that either were the most obvious, or that they were most comfortable with, despite admonitions in training to consider how effective their learning strategy was. Research to determine how to help people either choose effective strategies, or automate useful strategies (if these processes indeed prove to be automatic) is needed.

The efficiency with which employees acquire cognitively complex skills will continue to be an important training consideration for organizations as they move into the next century. Theoretically grounded research on how to help employees learn efficiently by making the most of their resources through effective self-regulation and optimal learning strategies will, someday, form the link between skill acquisition research and training in organizations. The present study attempted to take some initial steps toward this end by investigating the training implications of one major skill acquisition theory. Only follow up research on the most promising ways of improving and measuring learning and performance will enable I/O Psychologists to play a role in shaping training for organizations in the future.

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# APPENDIX A

# APPENDIX A

Consent Form

The study in which you are about to participate is designed to examine how individuals learn information and perform on a complex decision making task. You will be asked to learn material, participate in learning exercises, and to perform on a computer simulated radar tracking task in which you will measure the attributes of targets on the screen, classify targets, and decide what action should be taken. You will learn to prioritized targets and decide which ought to be acted upon first. In addition, you will be asked to complete a short measure of cognitive ability. You will answer questions about yourself, as well as about the tasks you will perform.

This experiment should last three hours. You will receive extra credit in your psychology course for your participation in this experiment. At the end of the experiment, you will be provided with written feedback explaining the purpose of the research in more detail.

Your participation in this study is strictly voluntary. You are free to discontinue participation in this experiment at any time for any reason without penalty. Your responses will be kept completely confidential. In addition, individuals will remain anonymous in any report of the research findings. You are free to ask any questions you might have about this study at any time. You may ask questions about the outcome of the research at any time by contacting Daniel Weissbein through the Department of Psychology by mail or you may call directly at 353-9166.

By signing this sheet, you agree that the researcher has explained the study to you, that you understand the procedures to be used, and that you freely consent to participate.

Date:_______ Name:___________________________

Signature:________________________

# APPENDIX B

# APPENDIX B

Demographic Questions

Please answer the following questions about yourself. All answers are will be kept strictly confidential.

1. Age:___

2. Sex: ____

3. Overall GPA: ____

4. Have you ever participated in an experiment in this lab before?
   Circle one: Yes No

6. How often do you play with video games?
   ___Never
   ___Rarely
   ___Sometimes
   ___Frequently
   ___Always

# APPENDIX C

# APPENDIX C

## Individual Instructions

During this part of the experiment, you will learning to operate a naval radar tracking simulator. Your job is to learn the information contained in this handbook to prepare yourself for the task.

### Situation Overview

You are the chief radar operator of the U.S.S. Valor, a U.S. Navy Aegis class missile cruiser. Your ship is currently stationed in the Hondo Gulf where political and military tensions are high.

You are seated on the bridge of the ship where you can receive information from the radar sensors on a computerized radar screen. Your mission is to protect your ship from hostile targets, but avoid destroying peaceful targets. The decisions that you make are critical. You are the main advisor to the Captain as to the course of action you should take against targets. Incorrect decisions could plunge the Hondo Gulf into all out war and result in the loss of the lives of you and your crew.

Your ship is at the center of the radar console. Surrounding the ship are a number of targets represented on the screen by asterisks. The sensors on your ship provide you with information you need to classify the targets according to their Type (air, submarine, or surface vessel), their Class (civilian or military), and their Intent (peaceful or hostile). You must first classify the target as Type air, submarine, or surface. Then you must classify the target as Class civilian or military. And, third you must classify the target's intent as peaceful or hostile.

Your goal is to protect the U.S.S. Valor and the surrounding fleet by correctly identifying the Type, Class, and Intent of the targets, and engaging them according to their Intent. That is, since the local government has been using both civilian and military aircraft, subs, and surface vessels for maneuvers, so you should base your Engagement response on the Intent of the target, peaceful or hostile. You should advise the captain to "Shoot" any hostile targets and "Clear" any peaceful targets. You must, however, make all four decisions (Type, Class, Intent, and Engage) accurately for the Captain to respond correctly. For instance, if you identify the target as an Air, Military, Hostile target and advise the Captain to Shoot, but the vessel was really Surface not Air, the wrong weapons will be selected. Therefore, you must make sure that all four decisions are made correctly in order to effectively respond to targets.

**Your Radar Console**

Your radar console looks like a computer. On the upper left corner you will see the time remaining in the scenario. When the time counts down to zero (0) the scenario is over. In the upper right corner of the console is the Score. You will receive 100 points for a correct engagement if ALL FOUR decisions are made correctly. If ANY of the four are made incorrectly, you will loose 100 points. Your job is ultimately to correctly engage as many targets as possible to get the highest score.

At the center of the console, you see the U.S.S. Valor, with a number of targets surrounding the ship. In the lower left corner of the screen you see the radius that your console is currently viewing. This indicates the distance from you ship the radar is currently displaying. You may look further out away from your ship by clicking on Zoom_Out on the OPER menu. You may focus the radar closer in by clicking on the Zoom_In function on the OPER menu.

On the lower right corner of the console, you see the Hooked Track #. Each of the targets on your console is given a number by the computer system on the Intrepid. You can hook a target by placing the cursor on a target with the mouse and clicking on it. The Hooked Track # display will show the number of that target. The information you gather will be gathered for that target. Examine Figure 1 to see a view of the radar screen as it might appear shortly after the start of a game.

On the far upper right corner of the console are the words OPER, TYPE, CLSS, & ITNT. These are pull-down menus. These menus allow you to gather the information you need to make the Type, Class, and Intent decision. The OPER menu has operator functions like Zoom_In, Zoom_Out, & Engage_ Shoot/Clear. The console will not allow you to engage a target until you have classified the Type, Class, and Intent. You must decide them in the following order:

(1) ID Air/Sub/Surface
(2) ID Civilian/Military
(3) ID Peaceful/Hostile

To display the contents of a menu, you click the right mouse button on the menu label. To display the information gathered by the sensors, place the pointer on the item and press and HOLD the right mouse button. The information will be displayed in the lower right hand corner until you release the mouse button. The console menus contain the following items:

| OPER | TYPE | CLSS | ITNT |
|---|---|---|---|
| End_Simulation | Speed | Initial_Bearing | Countermeasures |
| Start_Simulation | Altitude/Depth | Initial_Range | Electronic_Warfare |
| Zoom_In | Clime/Dive_Rate | Intelligence | Threat_Level |
| Zoom_Out | Signal_Strength | Direction_of_Origin | Response |
| ENGAGE_Shoot/ Clear | Communication_Time | Maneuvering_Pattern | Missile_Lock |
| Range | ID_Air/Sub/Surface | ID_Civilian/Military | ID_Peaceful/Hostile |

## Making Decisions

The first five items on the TYPE, CLSS, and ITNT menus provide you with the information you need to make the ID_Air/Sub/Surface, ID_Civilian/Military, and ID_Peaceful/Hostile decisions. When you choose an item from these menus, you receive the information value in the lower right corner of the console. There are rules (value ranges) to follow to interpret this information. Pay close attention to these rules. You must understand these rules to successfully engage targets. A "Review Sheet" in this handbook will help you remember these rules.

The type menu allows you to gather information to determine if the target is Air, Sub, or Surface. We will use information about the Target Speed to illustrate the rules for making the ID_Air/Sub/Surface decision. Possible Speed values and their meanings are as follows:

Speed > (greater than) 35 knots indicates an Aircraft (Type=Air)
Speed 25-35 knots indicates a Surface Vessel (Type=Surface)
Speed 0-24 knots indicates a Submarine (Type=Sub)

For example, the speed might be 115 knots. Since the target you have hooked is traveling above 35 knots the target Type is Air. Remember that speed is only one of five pieces of information you can use to make the determination of the Type. You also need to look up the target's Altitude/Depth, Climb/Dive Rate, Signal Strength, and Communication Time to determine the Type. It is up to you to determine when you have enough information to make a decision.

Once you have looked at all five pieces of information to make the Type decision, you will click the right mouse button on the ID_Air/Sub/Surface button, which allows you to identify the target as Air, Sub, or Surface according to your determination. A list of your alternatives will be displayed and you merely click on your choice.

Once you have made the decision, the symbol representing the target will change from an asterisk to another symbol to correspond with your decision. Air targets are represented by upper half symbols (⊓). Submarines are represented by lower half symbols (⊔). Surface vessels are represented by whole symbols (□).

When you make the Class decision, the symbols will change again to indicate civilian or military. Civilian targets are represented by curved symbols. Military targets are represented by sharp, angular, pointy symbols. The symbols are outlined below.

| | Air | Surface | Submarine |
|---|---|---|---|
| Civilian | ≈ | O | U |
| Military | Λ | ◊ | V |

The ITNT menu contains the five pieces of information you need to determine whether the target is peaceful or hostile. when you have gathered the five pieces of information needed to make this decision you click on "ID_Peaceful/Hostile" from to bottom of this menu and click on your decision to label the target as peaceful or hostile.

After you have made decisions regarding the targets Type, Class, and Intent, you are prepared to make a Final Engagement. To do this, you will open you OPER menu. Choose "Engage_Shoot/Clear" from this menu. Choose "Clear" for peaceful targets and "Shoot" for hostile targets.

<u>**Cue Conflict**</u>

Unfortunately, not all of the information you get will be perfectly accurate. For any given classification decision (Type, Class, or Intent) you may get information that is in conflict with other cues. That is one cue may tell you the target is Air and another cue might suggest the target is Sub! Or, one cue might suggest that the target is Military and another that the same target is Civilian! This can occur because aircraft sometimes attempt to disguise themselves, or sensors read information wrong. To deal with this **Cue Ambiguity**, you will need to measure cues until at least three agree. That is, three of five cues must agree for you to be confident of a decision. For example, if the ITNT menu gave you the following values:

Countermeasures - None <== Peaceful
Electronic Warfare - Big Bulge Radar <== Hostile
Threat Level - 3 <== Hostile
Response - Inaudible <== Unknown
Missile Lock - Locked <== Hostile

You can see by the indications provided on the right that the Countermeasures indicates that the target is Peaceful, the Response is Unknown, and the rest indicate Hostile. In this case, the answer is Hostile because three of five cues indicate hostile. However, not until you had checked all five could you have determined the correct threat level (assuming you checked them in order).

## Final Engagement Notes

When you choose Shoot or Clear, if you hold down the right mouse button as you choose, you will receive feedback in the lower right corner of the screen. This will tell you the targets actual Type, Class, and Intent, how you did, and whether you gained or lost the 100 points.

Once you have engaged a target it will disappear from your screen, you have no second chance to make the final engagement. You can reclassify the Type, Class, or Intent as long as you do so prior to the final engagement.

Don't forget that since any type of vessel can be used for hostile purposes, unusual combinations like Air-Civilian-Hostile may arise, but only the Intent is relevant for the Engage_Shoot/Clear decision. Likewise, Sub_Military_Peaceful should be cleared.

## Pop-Up Targets

Many times, targets go undetected until they are fairly close. This can happen due to broken sensors, bad weather, low flying aircraft, or stealth technology. You will see some targets suddenly appear on your screen. Therefore, you will have to stay alert because targets will "pop up" on your screen and may do so close to your ship or the fleet. These can be dangerous to you, so you must be aware of them.

## Penalty Circles

In order to maintain a safe distance between targets and your ship, as well as the fleet, operational orders dictate that there are zones which you may not let targets penetrate. These zones are called penalty circles, and if a target enters the penalty circle, you will loose points.

<u>The Inner Penalty Circle</u>

The Inner Penalty Circle is a circle indicated on the screen by a zone of 10 n.m. around your ship covered in a criss-cross pattern. This zone represents a safe zone around your ship. If a ship gets in this zone you will loose 50 points. You should prioritized the targets you choose to avoid letting targets into this zone as much as possible.

<u>The Outer Penalty Circle</u>

The Outer Penalty Circle is more complex, and more costly. The Outer Circle represents a zone around your whole fleet. You must protect the fleet as well as yourself. The outer penalty circle is INVISIBLE. It will not be shown on the screen. However, it is at 128 n.m. A way to estimate the location of the outer circle is to zoom out past 128 n.m. to 256 n.m. The penalty circle is now half way between the center of the radar and the edge of your screen. Note that zooming out to 128 will not help you to identify the targets just outside of the penalty circle because they will be outside of your viewing area. Therefore, zoom out to 256 n.m. and estimate half way between the edge of the screen and the center. This is the Outer Penalty Circle. If a target penetrates the Outer Penalty Circle, it will cost you 150 points!

Remember that targets will appear suddenly on the screen, so you must determine a strategy to guard the inner and outer circles. Once a target has penetrated the circle, you have lost the points for that target, it cannot go back out and re-enter the circle.

A final option on the console located in the OPER menu is the Range. Clicking this option will tell you a targets current range from your ship. This is the only cue value that will change over time (as a target moves closer or further away). This will be helpful for you when deciding how to prioritized targets. Especially when used in conjunction with Speed, Range can help you determine which targets are close to your penalty circles and fast.

**Review Sheet**
Type, Class, & Intent Information Values

**Type - Air/Sub/Surface**

| | AIR | SURFACE | SUB |
|---|---|---|---|
| **Speed** | > 35 knots | 25-35 knots | 0-24 knots |
| **Altitude/Depth** | > 0 feet | 0 feet | < 0 feet |
| **Climb/Dive Rate** | > 0 feet | 0 feet | < 0 feet |
| **Signal Strength** | Medium | High | Low |
| **Communication Time** | 0-40 s | 41-80 s | 81-120 s |

**Class - Civilian/Military**

| | CIVILIAN | UNKNOWN | MILITARY |
|---|---|---|---|
| **Initial Bearing** | 91-270 deg | 271-359 deg | 0-90 deg |
| **Initial Range** | 0-20 nm | 21-100 nm | > 100 nm |
| **Intelligence** | Platform | Unavailable | Private |
| **Direction of Origin** | Blue Lagoon | Unknown | Red Sea |
| **Maneuvering Pattern** | Code Foxtrot | Code Echo | Code Delta |

**Intent-Peaceful/Hostile**

| | PEACEFUL | UNKNOWN | HOSTILE |
|---|---|---|---|
| **Countermeasures** | None | Unknown | Jamming |
| **Electronic Warfare** | None | Undetected | Big Bulge Radar |
| **Treat Level** | 1 | 2 | 3 |
| **Response** | Given | Inaudible | No Response |
| **Missile Lock** | Clean | Undetectable | Locked |

APPENDIX D

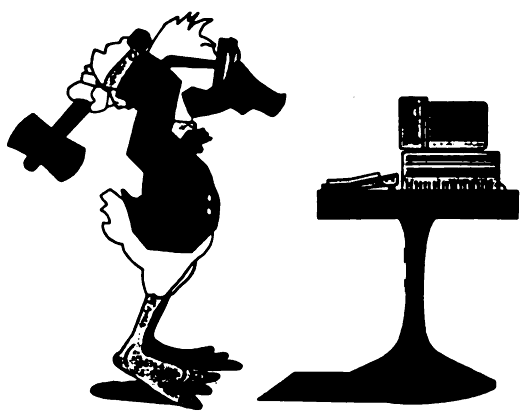
APPENDIX D

Metacognitive Training

# Thinking About Your Thinking!

# Metacognitive Training

Today, you are being asked to learn the radar simulation you saw a few minutes ago. Obviously, this simulation is complex: it has a number of different elements to learn in order to do well such as the cue values, the penalty circles locations, etc.. In order to do well, you will need to develop strategies to deal with learning and remembering the necessary material, as well as strategies for dealing with the task elements themselves, like cue conflict and penalty circles. In a few minutes you will be given time to study the material to prepare yourself. But, it is a lot of material to learn, and not a lot of time to learn it! You may feel like this when you are doing the simulation:



In order to help you deal with all of the learning you will be doing, let's take a few minutes to talk about an element of learning that most people do not consider:

## Thinking about your thinking!

Also called metacognition by some people (meta meaning "beyond" and "cognition" meaning thinking). By using the things we talk about here when you start learning the radar simulation information, you can help yourself to deal with all of the learning you will be doing. This will help you do better at the task, and any learning you do!

So, what do we mean when we talk about "thinking about your thinking"?

Metacognition can be thought of in terms of asking yourself three basic questions as you engage in the learning process:

---

1 What do I need to know?

2 How can I make sure I know the material well enough?

3 How can I evaluate and adapt my strategy to meet my learning needs?

Let's look at the 3 in order.

# What is important:

Choosing what is important is a matter of choosing which information:

- **you will need or use often**
- **is critical to reaching your goal**

Once you choose what is important you can mark it for special attention.

You probably do this when you highlight in your text books for class. By highlighting, you mark what material you want to give special attention when studying, which makes you more efficient! However, you probably do this without much thought. Here, you should try to actively determine what material is most important to you for the radar task, and mark it with a star or by circling it.

When you begin to study for the Radar Task, ask yourself: What will I use most often? What should I know from memory to score well? Then, focus your time on this material. Don't waste time with material that does not relate to scoring points or that you will rarely use.

# What is difficult:

Determining what will be difficult ahead of time may also help you to be efficient when you study. Material can be difficult to learn for a number of reasons. It could be:

| | | |
|---|---|---|
| Unfamiliar | Not Meaningful | Technical |
| Detailed | Very Similar | |

When you find material that will be difficult, but is important , you should consider your STRATEGY for learning.

What strategy do you typically use to memorize information ?

________________________________________

You probably use this strategy without much thought because it works for you most of the time. But, for difficult material, you may want to try something different.

For instance, let's say you wanted to remember the number "31" because that's how many people are in your class. Often people use repetition to learn. You could just say "31" to yourself over and over. But, it might be better if you associated the number 31 WITH something that was more meaningful.

Like Baskin-Robins 31 flavors.

You could picture yourself eating at "31 Flavors" with your class! The point is that when you find material that is particularly difficult, using another strategy, like association or imaging, will help you to remember it. But, you must consider your strategy and how well it is working !!!

Lets try an example of choosing what material will be the most difficult. On the next page, you will see information about helicopters similar to the kind you will need for the task.

*Draw a star next to the categories you think would be the hardest to memorize. Then, in the space provided, write what it is you think would be hard to learn about those categories!*

HELICOPTER IDENTIFICATION INFORMATION CHARTS

**HELICOPTER MAKE**

| | HUEY | APACHE | SIKORSKI |
|---|---|---|---|
| **LENGTH** | 30 Feet | 20 Feet | 40 Feet |
| **ROTOR SIZE** | Long | Short | Medium |
| **ROTOR SPEED** | 6,000 RPM | 10,000 RPM | 8,000 RPM |
| **RADAR RETURN** | Partial | Masked | Full |
| **PITCH** | Deep | High | Moderate |

**HELICOPTER USE**

| | CIVILIANS | ATTACK | CARGO |
|---|---|---|---|
| **IFF** | 3 | 1 | 2 |
| **CORRIDOR** | 0 - 53 | > 112 | 53 - 112 |
| **WEAPONS** | Unarmed | Fully Armed | Variable |
| **STEALTH** | None | Goblin | Stingray |
| **INFRA RED** | Visible | Invisible | Limited |

**Which three categories did you place a star next to, indicating that they would be the hardest to learn?**

1.____________________

2.____________________

3.____________________

**What about these categories made you think they will be difficult to learn?**

1. ____________________________________________________

2.____________________________________________________

3.____________________________________________________

Before moving on, let's try another exercise. Study the "Helicopter Use" chart you looked at earlier (listed again below). When you feel you know the information on the chart, stop and answer the questions on the following page.

HELICOPTER USE

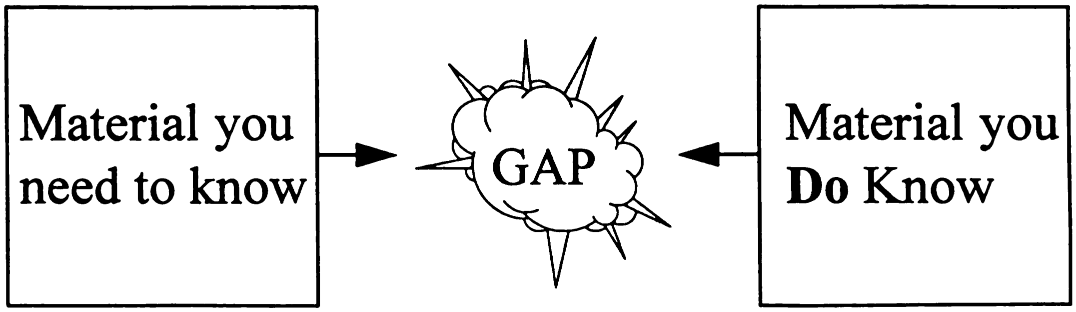
| | CIVILIANS | ATTACK | CARGO |
|---|---|---|---|
| IFF | 3 | 1 | 2 |
| CORRIDOR | 0 - 53 | > 112 | 53 - 112 |
| WEAPONS | Unarmed | Fully Armed | Variable |
| STEALTH | None | Goblin | Stingray |
| INFRA RED | Visible | Invisible | Limited |

1. The term “goblin” means the stealth is what?__________
2. If the corridor status is 115, what does this mean?__________
3. A cargo helicopter has what IFF?__________
4. If the weapons are “Variable” is this a civilian or Cargo Helicopter?________
5. If the Infra Red is 52, what is the helicopter used for?__________

# How Can I Make Sure I Know the Material Well Enough?

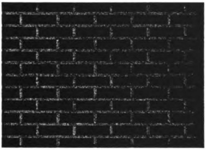
How did you do on the last exercise? The key to success is to realize that once you have determined which material is important to know, and what will be difficult to learn, you must go about the critical process of making sure you KNOW IT WELL ENOUGH.

You can think about this as looking for gaps between **what you need to know**, and what you **do know**!



That is, you are looking for holes in your learning. As you study, you must be monitoring your learning to make sure you are, in fact, filling in these gaps. Many times, people fail to actively do this, and they then don't know where they are weak. For example, they may say "I studied, and I thought I knew the information but then I only got a 'C' on the test." They did not catch the holes in their learning!

What student needs to know for a test



What they know


Likewise, on the last exercise, you might have felt like you knew the helicopter information, but then the questions were harder than you thought, and you may have found you didn't know the information as well as you thought.

To answer the essential question "do I know the material well enough?" you must determine how well you need to know it, vs. how well you do know it. Then, you can look for the gaps between the two!

## Determining how well you need to know material.

To determine how well you need to know information, think about the demands of the task. Do you need to know the details of information, or just the gist of it? Do you need to memorize information, or just be able to recognize it?

When studying, you should try to make your studying match the requirements of the test. So, when studying for an essay test, you would have yourself answer in essay form. The same holds true as you begin to study the material for the radar simulation. When you engage the radar task, you should think to yourself how will I need to use the information? What does the task tell me about a target, and what must I do WITH that information? Then match your study to the way you will use the information?

*What does the radar task tell you about the target's location? How will you need to use this? So, how should you learn it?*

Once you have determined how well you need to know the information, you can begin studying. Remember, some of the more difficult and important material you identified may need a different strategy or some extra attention!

Once you have studied for a while, you then must begin determining whether you know the information well enough.

# Making sure you know the information well enough!

Determining how well you actually know the material you are studying is a matter of probing your knowledge for gaps. One of the most effective ways to look for gaps is to SELF-TEST. Self-testing can take many forms, but it is basically forcing yourself to recall the information without looking at it. One way to be more efficient is to put a mark like a star, a check, or a dot next to material you get wrong as you are self-testing. Then you can go back and focus on the material you had the most trouble learning.

An example from the helicopter material you studied earlier would be if you turned over the paper and then forced yourself to recall the information by testing yourself with questions like "What 3 values go with stealth? Which value is for Civilians?" Then you would turn the page and correct yourself, putting a mark next to ones you got wrong. This way, you can give special focus to the ones that are wrong, or can try a new strategy to learn that information.

Let's try some self-testing. Take 4 min. to study the Helicopter Make chart below, copied from the charts you saw earlier. You will be asked to identify the make of helicopter associated with an attribute value (i.e you will be told "Pitch is high" and you will have to remember what kind of helicopter has a high pitch). Test yourself as you are learning. Put a mark next to information you have the most trouble with. Also, don't forget which information you determined would be the most difficult before!

**HELICOPTER MAKE**

| | HUEY | APACHE | SIKORSKI |
|---|---|---|---|
| LENGTH | 30 Feet | 20 Feet | 40 Feet |
| ROTOR SIZE | Long | Short | Medium |
| ROTOR SPEED | 6,000 RPM | 10,000 RPM | 8,000 RPM |
| RADAR RETURN | Partial | Masked | Full |
| PITCH | Deep | High | Moderate |

Now answer the following questions:

If the length is 20, is the helicopter a Huey, Apache, or Sikorski?_________

If the pitch is moderate, is the helicopter a Huey?_________

If the rotor speed is 10, 000 rpm, what kind of helicopter is it?________

Which helicopter has a Partial radar return? ________

Is a short rotor associated with an Apache or Sikorski ?_________

Did you get them all correct?_____

Were you able to determine in advance which you were going to have the most trouble with? ______ Why or why not?____

________________________________________________

How can you use self-testing when studying the material for the Radar Simulation task?____________________________

________________________________________________

________________________________________________

# How can I evaluate and adapt my strategy to meet my learning needs?

Finally, evaluating your strategy is an aspect of metacognition that is important to learning the radar simulation. While monitoring asks whether you are learning well enough, strategy evaluation asks whether the methods or approach you are using to perform is bringing you closer to your goal.

Here we are talking about your strategy for learning and performing on the task.

Often, when people begin a task they simply apply the first strategy or approach to the task that comes to mind, like trial and error. They generally don't consider whether it is a good strategy, and don't consider whether it is working. For the radar simulation, there are many possible strategies for cue conflict, penalty circles, and other aspects of the simulation. You should think about what approach you are using for dealing with these elements, and whether it is working. Remember, you will have 6 trials to work on the simulation. This means you will have chances to try to adapt your strategies.

You must consider your choice of strategy, whether it is working and how to improve it!

# 1. What strategy am I using?

The first step is to determine what strategy you are using or are going to use. Many times people use strategies without thinking about what they are doing. For example, trial and error is often used without considering other strategies. You should give some conscious thought to what strategy you are using to reach your goals.

# 2. Is it working well?

Step two is to consider after a period of time if your strategy is successful for you. Beginners will often fail to think about whether their approach is successful. They tend to stay with poor strategies too long, or switch from good ones too fast. You should consider how long yours will take to work.

You may have to consider how you will know if it is working! The computer gives you some information like if you go a target correct. But, this does not tell you necessarily whether your **strategy** is working. You will have to determine for yourself what information you need to tell you if your approach is working. Such as:

-how often targets go into your penalty circles,

-whether you are going faster,

-whether your score is improving, etc.

# 3. HOW CAN I IMPROVE IT?

The third step is to think about how to improve your strategy. What can you do to change or alter your approach that will overcome the difficulties you encountered? This may mean slight "tweaks" to your approach, or it may mean wholesale changes in your strategy. In either case, before you begin the next trial, you should have considered what you will do differently.

APPENDIX E

# APPENDIX E

Metacognitive Activity Questionnaire

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Strongly Disagree | | | Neutral | | | Strongly Agree |

Next to each statement, please indicate how much you agree or disagree with the statement baseed upon your behavior during the study period and on the task.

___ 1. I skimmed the material provided first to determine what would be the most difficult for me to learn.

___ 2. As I studied the material, I marked material that would be difficult for me to learn so that I could concentrate on it (e.g. highlight, star, etc).

___ 3. I tested myself regarding how well I knew the cue values.

___ 4. I DID NOT test myself as to how well I knew the location of the penalty circles.

___ 5. I **consciously** attempted to create a strategy to deal with the task.

___ 6. I DID NOT **purposefully** attempt to determine what strategy I was using to learn about the task.

___ 7. I **consciously** thought about what strategy I was using to learn the cue values.

___ 8. I **consciously** evaluated how well my task strategy or strategies were working.

___ 9. I **consciously** thought about how I could improve my strategy.

___ 10. I thought about how long my task strategy should take to show results.

___ 11. I attempted to monitor how well I was learning as I studied the material.

Appendix E (Cont'd)

___12. I planned how to learn as much of the material as I could in the time allowed.

___13. I thought about how I would need to use the material I was studying.

# APPENDIX F

Goal I

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# APPENDIX F

## Goal Directions

### Performance Goal Directions

GOAL 1 -- SCENARIOS 1 AND 2

On the first two scenarios, we would like you to reach a particular goal. **Your goal is to get -450 points** on the next two scenarios combined. That is, you should get **-200 to -250** points on each of the scenarios to follow. This is a challenging goal, but about 10% of the previous people who have done this task have attained these scores.

GOAL 2 -- SCENARIOS 3 AND 4

Now that you have had some practice with the task, we can set your sights a little higher. For the next two scenarios, **your goal is to reach the score of 100 points**. That is, you should try to get to the score of 100 across the next two scenarios combined. For example, by getting -100 on scenario 3 and then 200 points on scenario 4. This is a challenging goal, but 10% of the previous people who have done this task have attained these scores.

GOAL 3-- SCENARIOS 5 AND 6

Time for your final goal for the last two scenarios. For the next two scenarios, **your goal is to reach the score of -250 points**. That is, you should try to get to the score of -250 across the next two scenarios combined. For example, by getting 0 on scenario 5 and then -250 points on scenario 6. This is a challenging goal, but 10% of the previous people who have done this task have attained these scores.

Sequenced Subgoal Directions

GOAL 1
SCENARIOS 1 AND 2

It is important to have a good grasp of the information needed to make decisions. A solid grasp of this information will enable you to perform better later in the task. Therefore, **your goal over the next two scenarios is to commit the cue values and locations of the penalty circles to memory**.

You should focus your attention on the Review Sheet provided to you and memorize the values for the cues. The idea is that memorizing these now will mean you won't have to waste your time looking up the values on the review sheet each time as you go. For any given value of a cue, you should be able to tell without looking what that means about the target. For example, if you are told by the simulation "the Speed is 54 knots" you should know without looking that this cue value suggests the target is type AIR. This will allow you to concentrate more of your time and effort on perusing targets.

In addition, you should make sure you know the correct location of the penalty circles and where to zoom to engage them.

# GOAL 2
# SCENARIOS 3 AND 4

Now that you have had some experience with the task and have learned the cue values and penalty circle locations, it is time to understand the relationships between the task elements. One way to do this is to think about the task in terms of if-then relationships. That is, as action and reaction, or situation and action. So, for example, "if it is icy out and you want to stop, then you should pump the brakes of your car." This would be a statement about the elements of the situation (it is icy out and you want to stop) and the reaction (pump your brakes).

Your goal here is to generate the best set of rules that will help you to understand the task, particularly for the things you will have to make choice about such as target prioritization. Try to generate as complete a set as you can. Again, do not focus on your score, other than as feedback for helping you understand the relationships between task elements, or your actions and the results.

Read over the following 10 situation. Try to develop and end to these 10 statements over the next two trials. That is, try to understand what actions or decisions these situations would call for to get the best score later when you are trying for points.

If the first 3 cues in a decision agree,
then ________________________________________.

If I want to choose which target to engage next,
then ________________________________________.

If a target is moving faster than other targets,
then________________________________________.

If you have a choice between persuing a target threatening the inside penalty circle and the outside penalty circle,
then________________________________________.

If one target has penetrated a penalty circle but one has not,
then________________________________________.

If a target is not near either penalty circle, then
then________________________________________.

If you have been engaging targets near the inner penalty circle for a while,
then________________________________________.

If you want to find targets near the outer penalty circle,
then________________________________________.

If there are many targets threatening both penalty circles,
then________________________________________.

If you are engaging targets too slow, then
________________________________________.

## GOAL 3 -- SCENARIOS 5 AND 6

Now that you know the information and understand the task, it is time to perform! Now your score counts! Time for your final goal for the last two scenarios. For the next two scenarios, **your goal is to reach the score of -250 points**. That is, you should try to get to the score of -250 across the next two scenarios combined. For example, by getting 0 on scenario 5 and then -250 points on scenario 6. This is a challenging goal, but 10% of the previous people who have done this task have attained these scores.

APPENDIX G

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# APPENDIX G

Goal Committment Questionnaire

Circle the number that indicates your commitment to the goal you were assigned.

1. How hard are you willing to work to achieve the assigned goal?

1 2 3 4 5 6 7 8

Exteremely Hard — Not At All Hard

2. I am willing to put forth a great deal of effort to reach my assigned goal.

1 2 3 4 5 6 7 8

Strongly Agree — Strongly Disagree

3. How committed are you to working as hard as possible to reach the assigned goal?

1 2 3 4 5 6 7 8

Extremely Committed — Extremely Uncommitted

APPENDIX H

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# APPENDIX H

Knowledge Test

Please circle the letter corresponding to the correct answer.

1. The location (in nautical miles) of the outer penalty circle is:

   a. 512
   b. 256
   c. 10
   d. 128

2. An initial bearing of 85 indicates that the target is:

   a. Unknown
   b. Hostile
   c. Military
   d. Civilian

3. The Code Delta Maneuvering pattern indicates which of the following? The target is:

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

4. A submarine might have which of the following Communication Times:

   a. 41
   b. 110
   c. 40
   d. 50

5. The threat level which would indicate a hostile target is:

   a. 1
   b. 2
   c. 3
   d. 4

6. Which of the following is an indication that the target is Hostile?

   a. Direction of Origin = Red Sea
   b. Maneuvering pattern = Code Echo
   c. Response = Given
   d. Missile Lock = Locked

7. If a target is outside the range of your screen your best option to view the target is to:

   a. Wait for it to come into view.
   b. Ignore it if it is outside of the view because it cannot cause problems that far away.
   c. Zoom out to engage the target.
   d. There is nothing you can do to engage the target.

8. Assume that at the start of the scenario there are two targets one by each penalty circle. Both targets are traveling at 250 knots and are 13 nm from their respective penalty circles. Which target should you engage first?

   a. the target near the inner penalty circle
   b. the target near the outer penalty circle
   c. it does not matter, both are equal
   d. engage the target with the highest Initial Range

9. If you notice three targets clustered together near a penalty circle, how will you determine which to engage first?

   a. Check the Initial Ranges
   b. Check the Speeds
   c. Check both Range and Speed
   d. Zoom out to 516 the outer penalty circle and engage the target closest to the center (your own ship)

10. Which menu would you select to Zoom Out?

   a. Operator
   b. Type
   c. Class
   d. Intent

11. What is the minimum number of cues needed to ensure a correct type decision?

    a. 1
    b. 2
    c. 3
    d. 4

12. An Initial Range of 300 nm indicates that the target is:

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

13. A target with which of the following could be Military? A target with:

    a. Initial Range = 10nm.
    b. Maneuvering Pattern of Code Foxtrot.
    c. Initial Range = 110nm.
    d. Direction of Origin = Blue Lagoon.

14. "Big Bulge Radar" is the Hostile value signal for which of the following attributes:

    a. Electronic Warfare
    b. Countermeasures
    c. Response
    d. Intelligence

15. What is the fastest possible speed for a surface vessel?

    a. 25 knots
    b. 24 knots
    c. 35 knots
    d. 34 knots

16. Surface Vessels could have a signal strength of:

    a. 1
    b. High
    c. Medium
    d. Low

17. If you have just engaged three targets near the Inner Penalty Circle, which of the following should you do next?

    a. Engage the next target nearest to the Inner Penalty Circle
    b. Engage the fastest target near the Inner Penalty Circle
    c. Zoom out to check the Outer Penalty Circle.
    d. Zoom in to check how close targets are to your own ship.

18. If you have three targets,
target (a) with Range = 120 nm, Speed = 150 knots
target (b) with Range = 130 nm , Speed = 100 knots, and
target (c) with Range = 8 nm, Speed = 150 knots,
which target should you engage first?

    a. target a
    b. target b
    c. target c
    d. any order, it will not matter

19. If you have three targets,
target (a) with Range = 8 nm, Speed = 150 knots
target (b) with Range = 12 nm , Speed = 150 knots, and
target (c) with Range = 8 nm, Speed = 200 knots,
which target should you engage first?

    a. target a
    b. target b
    c. target c
    d. any order, it will not matter

20. Suppose you had the following three targets:
target (1) which is air, military, and hostile at 125 n.m.
target (2) which is air, civilian, and peaceful at 9 n.m.
target (3) which is sub, miliary, hostile at 5 n.m.
which target would you engage first?

    a. target 1
    b. target 2
    c. target 3
    d. it does not matter which target based upon this information

APPENDIX I

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# APPENDIX I

Learning Activity Questionnaire

Circle the number corresponding to the answer that best represents the frequency or amount that you did the following:

1. To what extent did you use mental rehearsal to learn the material contained in the handbook and review sheet (e.g. cue values, penalty circle locations, etc.)?

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Very Little | | | To Some Extent | | | A Great Deal |

2. To what extent did you list (as in write several times) material contained in the handbook and review sheet to help you remember this information?

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Very Little | | | To Some Extent | | | A Great Deal |

3. To what extent did you use mnemonic devices to help you remember material contained in the handbook and review sheet?

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Very Little | | | To Some Extent | | | A Great Deal |

4. To what extent did you underline information contained in the handbook or review sheet that you wanted to learn?

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Very Little | | | To Some Extent | | | A Great Deal |

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5. To what extent did you associate information contained in the handbook or reveiw sheet that you wanted to learn with something you already knew?

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Very Little | | | To Some Extent | | | A Great Deal |

6. To what extent did you think about how to apply information you were learning to the task itself?

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Very Little | | | To Some Extent | | | A Great Deal |

7. How often did you hook targets just to practice learning cue values, not to score points?

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Very Little | | | To Some Extent | | | A Great Deal |

8. How often did you check a target's range and speed just to practice prioritizing targets not to score points?

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Very Little | | | To Some Extent | | | A Great Deal |

9. How much time did you spend exploring the task to gain an understanding of the task not trying to score points?

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Very Little | | | Some | | | A Great Deal |

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10. How much time did you spend trying to understand the abstract concepts underlying the task?

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Very Little | | | Some | | | A Great Deal |

11. To what extent did you spend time trying to observe and reflect upon the task?

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Very Little | | | To Some Extent | | | A Great Deal |

12. To what extent did you try and summarize the material you were trying to learn in your own words?

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Very Little | | | To Some Extent | | | A Great Deal |

13. To what extent did you try and devise a system for recalling the important material?

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Very Little | | | To Some Extent | | | A Great Deal |

14. To what extent did you try and think of rules of thumb for the task?

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Very Little | | | To Some Extent | | | A Great Deal |

15. To what extent did you try to generate metaphors which would help you learn the material or understand the task?

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Very Little | | | To Some Extent | | | A Great Deal |

16. To what extent did you generate and test hypotheses to help you learn about the task?

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Very Little | | | To Some Extent | | | A Great Deal |

17. To what extent did you experiment with a new strategy to see if it would work?

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|
| Very Little | | | To Some Extent | | | A Great Deal |

APPENDIX J

# APPENDIX J

Post Scenario Questions

Please indicate on the following line what exactly you did during the last scenario to reach your goal. Be as specific as possible as to what you were trying to accomplish and how you attempted to do this.

Scenario 1

______________________________________________

______________________________________________

______________________________________________

______________________________________________

Scenario 2

______________________________________________

______________________________________________

______________________________________________

______________________________________________

Scenario 3

______________________________________________

______________________________________________

______________________________________________

______________________________________________

Scenario 4

Scenario 5

Scenario 6

APPENDIX K

# APPENDIX K

Debriefing Sheet

The experiment in which you just took part was designed to examine the effects of various types of goal and training on the acquisition of a complex skill. The study is comparing the learning and performance of people who receive training on metacognition (thinking about thinking) to those who do not receive this training in order to determine if this type of training can enhance learning and performance under either performance goals or sequenced subgoals. Prior research elsewhere had questioned the usefulness of goals early in skill acquisition, and this research examines how to make goals useful during this time. This research has implications for helping people to more efficiently use their resources to acquire complex skills, such as the task you performed.

If you have any concerns or questions, or you would like to learn the results of the study, you can write to Daniel Weissbein in 129 Psychology research, or call directly at 353-9166.

# APPENDIX L

# APPENDIX L

Instructions to Raters

Please rate the subjects' responses on the Post Scenario Questionnaire in terms of thier metacognitive content. I would like you to use a 1 to 7 format, with 1 being the lowest possible rating. You will have to use your best judgment, some people will not have much to rate (some people will have no metacognitive content of course). You are looking for the overall quality of their metacognitive activity based on your examination of their writing. As you know, metacognition involves thinking about thinking. On the Post Scenario Questionnaries, this is likely to take the following forms:

| TYPE: | EXAMPLES: |
|---|---|
| Strategy evaluation | -I did X but it did not seem to work<br>-My strategy allowed too many to go into the inner circle |
| Identification of flaws or improvement in knowledge | -I did not know the important information<br>-I know the cues better<br>-The Type decision is harder than the other decisions for me |
| Identification of difficult information | -I am having trouble learning the Initial Bearing |
| Self-Testing | -I used self-testing to learn the cues<br>-I forced myself not to look at the review sheet as I progressed |
| Strategy Change due to flaw | -Since before I was missing the ones in the inner circle, now I will try the outer more |
| Others | -misc. things you determine to indicate diagnosis and prescription for cognitive shortcomings |

Notes on rating:

- Having a strategy is not metacognitive
- Just saying "I went faster" or "I need to go faster" is not metacognitive unless you see it as a strategic point
- Not looking at the review sheet only counts if it is on purpose or noted as an assessment of knowledge
- "I'm doing well" only counts if it is tied to a strategy evaluation
- It is NOT metacognitive if they are saying they did well AT a strategy

# APPENDIX M

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# APPENDIX M

Mediation tests -- Metacognitive training on knowledge through Metacognitive activity

Hierarchical Regression Results of the Test of Hypotheses 8a -- The mediation of the effects of Metacognitive Training on Declarative Knowledge Through Metacognitive Activity

| VARIABLE | β | $\Delta R^2$ | $R^2$ |
|---|---|---|---|
| EQUATION 1 | | | |
| Step 1: | | | |
| Cognitive Ability | .30** | .121** | .12** |
| Goal Commitment | .07 | | |
| Step 2: | | | |
| M.C. Activity (tally) | -.08 | .013 | .13* |
| M.C. Activity (score) | .04 | | |
| M.C. Activity (rating) | .08 | | |
| Step 3: | | | |
| M.C. Training | -.06 | .002 | .14* |
| EQUATION 2 | | | |
| STEP 1: | | | |
| Cognitive Ability | .30** | .121** | .12** |
| Goal Commitment | .07 | | |
| STEP 2: | | | |
| M.C. Training | -.06 | .007 | .13** |
| STEP 3: | | | |
| M.C. Activity (tally) | -.08 | .008 | .14* |
| M.C. Activity (score) | .04 | | |
| M.C. Activity (rating) | .08 | | |

*p<.05, **p<.01
n = 106

Hierarchical Regression Results of the Test of Hypotheses a -- The mediation of the effects of Metacognitive Training on Procedural Knowledge Through Metacognitive Activity

| VARIABLE | β | ΔR² | R² |
|---|---|---|---|
| EQUATION 1 | | | |
| Step 1: | | | |
| Cognitive Ability | .31** | .146** | .15** |
| Goal Commitment | .05 | | |
| Step 2: | | | |
| M.C. Activity (tally) | -.06 | .026 | .17* |
| M.C. Activity (score) | .07 | | |
| M.C. Activity (rating) | .18 | | |
| Step 3: | | | |
| M.C. Training | .04 | .001 | .17* |
| EQUATION 2 | | | |
| STEP 1: | | | |
| Cognitive Ability | .31** | .145** | .15** |
| Goal Commitment | .05 | | |
| STEP 2: | | | |
| M.C. Training | .04 | .000 | .15** |
| STEP 3: | | | |
| M.C. Activity (tally) | -.06 | .028 | .17* |
| M.C. Activity (score) | .07 | | |
| M.C. Activity (rating) | .18 | | |

*p<.05, **p<.01
n = 106

APPENDIX N

# APPENDIX N

Mediation Tests – The effects of Metacognitive Training on Performance Variables

Hierarchical Regression Results of the Test of Hypotheses 8b – The mediation of the effects of Metacognitive Training and Activity on Score Through Knowledge

| VARIABLE | β | ΔR² | R² |
|---|---|---|---|
| EQUATION 1 | | | |
| STEP 1: | | | |
| Cognitive Ability | -.05 | .064* | .06* |
| Goal Commitment | .04 | | |
| STEP 2: | | | |
| Declarative | .29** | .166** | .23** |
| Procedural | .30** | | |
| STEP 3: | | | |
| M.C. Activity (tally) | -.06 | .021 | .25** |
| M.C. Activity (score) | .05 | | |
| M.C. Activity (rating) | .14 | | |
| STEP 4: | | | |
| M.C. Training | -.07 | .004 | .26** |
| EQUATION 2 | | | |
| STEP 1: | | | |
| Cognitive Ability | -.06 | .064* | .06* |
| Goal Commitment | .04 | | |
| STEP 2: | | | |
| M.C. Training | -.07 | .017 | .08* |
| STEP 3: | | | |
| M.C. Activity (tally) | -.06 | .040 | .12* |
| M.C. Activity (score) | .05 | | |
| M.C. Activity (rating) | .14 | | |
| STEP 4: | | | |
| Declarative | .29** | .135** | .26** |
| Procedural | .30** | | |

*p<.05, **p<.01, n = 106

Hierarchical Regression Results of the Test of Hypotheses 8b – The mediation of the effects of Metacognitive Training and Activity on Correct Decisions Through Knowledge

| VARIABLE | β | $\Delta R^2$ | $R^2$ |
|---|---|---|---|
| <u>EQUATION 1</u> | | | |
| STEP 1: | | | |
| Cognitive Ability | -.06 | .081 | .08 |
| Goal Commitment | .12 | | |
| STEP 2: | | | |
| Declarative | .31** | .16** | .24** |
| Procedural | .25** | | |
| STEP 3: | | | |
| M.C. Activity (tally) | -.18 | .045 | .28** |
| M.C. Activity (score) | .02 | | |
| M.C. Activity (rating) | .19 | | |
| STEP 4: | | | |
| M.C. Training | -.07 | .005 | .29** |
| <u>EQUATION 2</u> | | | |
| STEP 1: | | | |
| Cognitive Ability | -.06 | .081 | .08* |
| Goal Commitment | .12 | | |
| STEP 2: | | | |
| M.C. Training | -.07 | .028 | .11** |
| STEP 3: | | | |
| M.C. Activity (tally) | -.18 | .057 | .17** |
| M.C. Activity (score) | .02 | | |
| M.C. Activity (rating) | .19 | | |
| STEP 4: | | | |
| Declarative | .25** | .122** | .29** |
| Procedural | .31** | | |

*p<.05, **p<.01
n = 106

Hierarchical Regression Results of the Test of Hypotheses 8b -- The mediation of the effects of Metacognitive Training and Activity on Outer Penalty Circle Intrusions through Knowledge

| VARIABLE | β | ΔR² | R² |
|---|---|---|---|
| <u>EQUATION 1</u> | | | |
| STEP 1: | | | |
| Cognitive Ability | -.06 | .046 | .05 |
| Goal Commitment | -.03 | | |
| STEP 2: | | | |
| Declarative | .08 | .060** | .11* |
| Procedural | .27** | | |
| STEP 3: | | | |
| M.C. Activity (tally) | -.18 | .027 | .13* |
| M.C. Activity (score) | -.10 | | |
| M.C. Activity (rating) | .14 | | |
| STEP 4: | | | |
| M.C. Training | .07 | .004 | .14 |
| <u>EQUATION 2</u> | | | |
| STEP 1: | | | |
| Cognitive Ability | -.06 | .046 | .05 |
| Goal Commitment | -.03 | | |
| STEP 2: | | | |
| M.C. Training | -.07 | .001 | .05 |
| STEP 3: | | | |
| M.C. Activity (tally) | -.17 | .028 | .08 |
| M.C. Activity (score) | -.10 | | |
| M.C. Activity (rating) | .14 | | |
| STEP 4: | | | |
| Declarative | -.08 | .061* | .13 |
| Procedural | -.26* | | |

*p<.05, **p<.01
n = 106

Hierarchical Regression Results of the Test of Hypotheses 8b – The mediation of the effects of Metacognitive Training and Activity on Inner Penalty Circle Intrusions through Knowledge

| VARIABLE | β | $\Delta R^2$ | $R^2$ |
|---|---|---|---|
| <u>EQUATION 1</u> | | | |
| STEP 1: | | | |
| Cognitive Ability | .02 | .006 | .01 |
| Goal Commitment | .18 | | |
| STEP 2: | | | |
| Declarative | -.03 | .015 | . 02 |
| Procedural | .15* | | |
| STEP 3: | | | |
| M.C. Activity (tally) | -.05 | .075* | .10 |
| M.C. Activity (score) | -.27* | | |
| M.C. Activity (rating) | -.03 | | |
| STEP 4: | | | |
| M.C. Training | .16 | .020 | .12 |
| <u>EQUATION 2</u> | | | |
| STEP 1: | | | |
| Cognitive Ability | .02 | .006 | .01 |
| Goal Commitment | .18 | | |
| STEP 2: | | | |
| M.C. Training | .16 | .027 | .03 |
| STEP 3: | | | |
| M.C. Activity (tally) | -.05 | .064 | .10 |
| M.C. Activity (score) | -.27* | | |
| M.C. Activity (rating) | -.03 | | |
| STEP 4: | | | |
| Declarative | -.02 | .020 | .12 |
| Procedural | .15 | | |

*$p<.05$, **$p<.01$

n = 106

# APPENDIX O

# APPENDIX O

Mediation Tests – The effects of Goal Type on Knowledge

Hierarchical Regression Results of the Test of Hypotheses 9a – The mediation of the effects of Goal Type on Declarative Knowledge through Learning and Metacognitive Activity

| VARIABLE | β | $\Delta R^2$ | $R^2$ |
|---|---|---|---|
| EQUATION 1 | | | |
| STEP 1: | | | |
| Cognitive Ability | .30** | .146** | .15** |
| Goal Commitment | .06 | | |
| STEP 2 | | | |
| Learning Activity (tally) | -.06 | .037 | .18** |
| M.C. Activity (tally) | -.04 | | |
| Learning Activity (score) | -.04 | | |
| M.C. Activity (score) | .07 | | |
| M.C. Activity (rating) | .18 | | |
| STEP 3: | | | |
| Goal Type | -.09 | .008 | .19* |
| EQUATION 2 | | | |
| STEP 1: | | | |
| Cognitive Ability | .29** | .146** | .15** |
| Goal Commitment | .05 | | |
| STEP 2: | | | |
| Goal Type | .13 | .013 | .16** |
| STEP 3: | | | |
| M.C. Activity (tally) | -.04 | .031 | .19* |
| Learning Activity (tally) | -.06 | | |
| Learning Activity (score) | -.04 | | |
| M.C. Activity (rating) | .18 | | |
| M.C. Activity (score) | .07 | | |

*p<.05, **p<.01
n = 106

Hierarchical Regression Results of the Test of Hypotheses 9a -- The mediation of the effects of Goal Type on Procedural Knowledge through Learning and Metacognitive Activity

| VARIABLE | β | ΔR² | R² |
|---|---|---|---|
| <u>EQUATION 1</u> | | | |
| STEP 1: | | | |
| Cognitive Ability | .02 | .121** | .12** |
| Goal Commitment | .18 | | |
| STEP 2 | | | |
| Learning Activity (tally) | -.13 | .021 | .14 |
| M.C. Activity (tally) | -.10 | | |
| Learning Activity (score) | .01 | | |
| M.C. Activity (rating) | .12 | | |
| M.C. Activity (score) | .05 | | |
| STEP 3: | | | |
| Goal Type | .13 | .016 | .16* |
| <u>EQUATION 2</u> | | | |
| STEP 1: | | | |
| Cognitive Ability | .29** | .121** | .12** |
| Goal Commitment | .05 | | |
| STEP 2: | | | |
| Goal Type | .13 | .008 | .13* |
| STEP 3: | | | |
| M.C. Activity (tally) | -.10 | .029 | .16* |
| Learning Activity (tally) | -.13 | | |
| Learning Activity (score) | .01 | | |
| M.C. Activity (score) | .05 | | |
| M.C. Activity (rating) | .11 | | |

*p<.05, **p<.01
n = 106

APPENDIX P

# APPENDIX P

Mediation Tests – The effects of Goal Type on Performance Variables

Hierarchical Regression Results of the Test of Hypotheses 9b – The mediation of the effects of Goal Type on Score through Learning Activity, Metacognitive Activity, and Knowledge

| VARIABLE | β | $\Delta R^2$ | $R^2$ |
|---|---|---|---|
| EQUATION 1 | | | |
| STEP 1: | | | |
| Cognitive Ability | -.04 | .064* | .06** |
| Goal Commitment | .06 | | |
| STEP 2: | | | |
| Declarative | .32** | .166** | .23** |
| Procedural | .28** | | |
| STEP 3: | | | |
| Learning Activity (tally) | -.08 | .026 | .26** |
| M.C. Activity (tally) | -.09 | | |
| Learning Activity (score) | -.07 | | |
| M.C. Activity (score) | .05 | | |
| M.C. Activity (rating) | .15 | | |
| STEP 4: | | | |
| Goal Type | -.17 | .026 | .28** |
| EQUATION 2 | | | |
| STEP 1: | | | |
| Cognitive Ability | -.04 | .064* | .05* |
| Goal Commitment | .06 | | |
| STEP 2: | | | |
| Goal Type | -.17 | .025 | .09* |
| STEP 3: | | | |
| M.C. Activity (tally) | -.08 | .054 | .14* |
| Learning Activity (tally) | .08 | | |
| Learning Activity (score) | -.07 | | |
| M.C. Activity (score) | .07 | | |
| M.C. Activity (rating) | .15 | | |

Appendix P (Cont'd)

| VARIABLE | $\beta$ | $\Delta R^2$ | $R^2$ |
|---|---|---|---|
| STEP 4: | | | |
| Declarative | .32** | .139** | .28** |
| Procedural | .28** | | |

*p<.05, **p<.01, n = 106

Hierarchical Regression Results of the Test of Hypotheses 9b -- The mediation of the effects of Goal Type on Number Engaged through Learning Activity, M.C. Activity, and Knowledge

| VARIABLE | β | $\Delta R^2$ | $R^2$ |
|---|---|---|---|
| <u>EQUATION 1</u> | | | |
| STEP 1: | | | |
| Cognitive Ability | .00 | .042 | .04 |
| Goal Commitment | .13 | | |
| STEP 2: | | | |
| Declarative | .16 | .037 | .08 |
| Procedural | .10 | | |
| STEP 3: | | | |
| Learning Activity (tally) | .06 | .048 | .13 |
| M.C. Activity (tally) | -.21* | | |
| Learning Activity (score) | -.11 | | |
| M.C. Activity (score) | .09 | | |
| M.C. Activity (rating) | .12 | | |
| STEP 4: | | | |
| Goal Type | .09 | .008 | .14 |
| <u>EQUATION 2</u> | | | |
| STEP 1: | | | |
| Cognitive Ability | .00 | .043 | .04 |
| Goal Commitment | .13 | | |
| STEP 2: | | | |
| Goal Type | .09 | .011 | .05 |
| STEP 3: | | | |
| M.C. Activity (tally) | -.21* | .055 | .11 |
| Learning Activity (tally) | .06 | | |
| Learning Activity (score) | -.11 | | |
| M.C. Activity (score) | .09 | | |
| M.C. Activity (rating) | .12 | | |
| STEP 4: | | | |
| Declarative | .16 | .027 | .14 |
| Procedural | .10 | | |

*$p<.05$, **$p<.01$, n = 106

Hierarchical Regression Results of the Test of Hypotheses 9b – The mediation of the effects of Goal Type on Correct Decisions through Learning Activity, M.C. Activity, and Knowledge

| VARIABLE | β | ΔR² | R² |
|---|---|---|---|
| EQUATION 1 | | | |
| STEP 1: | | | |
| Cognitive Ability | -.05 | .08** | .08** |
| Goal Commitment | .14 | | |
| STEP 2: | | | |
| Declarative | .33** | .157** | .24** |
| Procedural | .25** | | |
| STEP3: | | | |
| Learning Activity (tally) | .11 | .061 | .30** |
| M.C. Activity (tally) | -.22* | | |
| Learning Activity (score) | -.12 | | |
| M.C. Activity (score) | .07 | | |
| M.C. Activity (rating) | .20 | | |
| STEP 4: | | | |
| Goal Type | -.08 | .005 | .30** |
| EQUATION 2 | | | |
| STEP 1: | | | |
| Cognitive Ability | -.05 | .081** | .08** |
| Goal Commitment | .14 | | |
| STEP 2: | | | |
| Goal Type | -.08 | .003 | .08* |
| STEP 3: | | | |
| M.C. Activity (tally) | -.21* | .091 | .18* |
| Learning Activity (tally) | .11 | | |
| Learning Activity (score) | -.12 | | |
| M.C. Activity (score) | .07 | | |
| M.C. Activity (rating) | .20 | | |
| STEP 4: | | | |
| Declarative | .33** | .129** | .30** |
| Procedural | .25** | | |

*p<.05, **p<.01, n = 106

Hierarchical Regression Results of the Test of Hypotheses 9b -- The mediation of the effects of Goal Type on Penalty Points through Learning Activity, M.C. Activity, and Knowledge

| VARIABLE | β | $\Delta R^2$ | $R^2$ |
|---|---|---|---|
| <u>EQUATION 1</u> | | | |
| STEP 1: | | | |
| Cognitive Ability | .00 | .030 | .03 |
| Goal Commitment | .13 | | |
| STEP 2: | | | |
| Declarative | -.09 | .037 | .07 |
| Procedural | -.17 | | |
| STEP 3: | | | |
| Learning Activity (tally) | .04 | .055 | .12 |
| M.C. Activity (tally) | -.13 | | |
| Learning Activity (score) | .00 | | |
| M.C. Activity (score) | -.21 | | |
| M.C. Activity (rating) | .07 | | |
| STEP 4: | | | |
| Goal Type | .04 | .001 | .12 |
| <u>EQUATION 2</u> | | | |
| STEP 1: | | | |
| Cognitive Ability | -.07 | .034 | .03 |
| Goal Commitment | .06 | | |
| STEP 2: | | | |
| Goal Type | .04 | .005 | .04 |
| STEP 3: | | | |
| M.C. Activity (tally) | -.14 | .059 | .09 |
| Learning Activity (tally) | .04 | | |
| Learning Activity (score) | .00 | | |
| M.C. Activity (score) | -.22 | | |
| M.C. Activity (rating) | .07 | | |
| STEP 4: | | | |
| Declarative | -.09 | .029 | .12 |
| Procedural | -.17 | | |

*p<.05, **p<.01, n = 106

Hierarchical Regression Results of the Test of Hypotheses 9b – The mediation of the effects of Goal Type on Outer P.C. Intrusions through Learning Activity, M.C. Activity, and Knowledge

| VARIABLE | β | ΔR² | R² |
|---|---|---|---|
| EQUATION 1 | | | |
| STEP 1: | | | |
| Cognitive Ability | -.07 | .046 | .05 |
| Goal Commitment | -.03 | | |
| STEP 2: | | | |
| Declarative | -.09 | .059* | .11* |
| Procedural | -.26* | | |
| STEP 3: | | | |
| Learning Activity (tally) | .01 | .028 | .13 |
| M.C. Activity (tally) | -.15 | | |
| Learning Activity (score) | .02 | | |
| M.C. Activity (score) | -.11 | | |
| M.C. Activity (rating) | .11 | | |
| STEP 4: | | | |
| Goal Type | .06 | .003 | .14 |
| EQUATION 2 | | | |
| STEP 1: | | | |
| Cognitive Ability | -.07 | .047 | .05 |
| Goal Commitment | -.03 | | |
| STEP 2: | | | |
| Goal Type | .06 | .007 | .05 |
| STEP 3: | | | |
| M.C. Activity (tally) | -.15 | .027 | .08 |
| Learning Activity (tally) | .01 | | |
| Learning Activity (score) | .02 | | |
| M.C. Activity (score) | -.10 | | |
| M.C. Activity (rating) | .11 | | |
| STEP 4: | | | |
| Declarative | -.08 | .056* | .14 |
| Procedural | -.25* | | |

*p<.05, **p<.01, n = 106

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Hierarchical Regression Results of the Test of Hypotheses 9b – The mediation of the effects of Goal Type on Inner P.C. Intrusions through Learning Activity, M.C. Activity, and Knowledge

| VARIABLE | β | ΔR² | R² |
|---|---|---|---|
| <u>EQUATION 1</u> | | | |
| STEP 1: | | | |
| Cognitive Ability | .00 | .006 | .01 |
| Goal Commitment | .21 | | |
| STEP 2: | | | |
| Declarative | -.03 | .015 | .02 |
| Procedural | .15 | | |
| STEP 3: | | | |
| Learning Activity (tally) | .07 | .078 | .10 |
| M.C. Activity (tally) | .01 | | |
| Learning Activity (score) | -.03 | | |
| M.C. Activity (score) | -.28* | | |
| M.C. Activity (rating) | -.09 | | |
| STEP 4: | | | |
| Goal Type | -.04 | .001 | .10 |
| <u>EQUATION 2</u> | | | |
| STEP 1: | | | |
| Cognitive Ability | .00 | .006 | .01 |
| Goal Commitment | .21 | | |
| STEP 2: | | | |
| Goal Type | -.04 | .001 | .01 |
| STEP 3: | | | |
| M.C. Activity (tally) | .01 | .073 | .08 |
| Learning Activity (tally) | .07 | | |
| Learning Activity (score) | -.02 | | |
| M.C. Activity (score) | -.28* | | |
| M.C. Activity (rating) | -.09 | | |
| STEP 4: | | | |
| Declarative | -.02 | .021 | .10 |
| Procedural | .15 | | |

*$p<.05$, **$p<.01$, n = 106