

Yin and Yang Cognitive Motivational Processes
Operating in Multimedia Learning Environments¹

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Abstract

The purpose of this discussion is to make the point that the complexity and flexibility of multi-media instructional environments can be beneficial but may also bring a large and almost unrecognized danger. Instructional conditions associated with multi-media environments that both help and hinder student learning motivation are described. The first part of the presentation attempts to link research on complex learning and cognitive load on the one hand, and motivational variables that are necessary to support learning, on the other hand. Following Pajares (1996) the discussion engages in “inter-theoretical cross talk” (p. 569) and so draws freely on the many small theories and research hypotheses suggested by research in a variety of learning and motivation traditions, keeping in mind the cautions of Gery D’Ydewalle (1987) concerning the many problems with motivational constructs. Five hypotheses are suggested that attempt to explain why motivation for complex learning may sometimes be damaged by MMI instructional conditions that, for example, overload working memory and/or provide new learning strategies.

- H1. As cognitive load increases, mental effort increases linearly and positively.
- H2. Mental effort has an inverted U relationship with task self efficacy so that self efficacy decreases as task novelty increases and vice versa.
- H3. At the “efficacy threshold” effort stops and an automated cognitive “default” directs attention to different or novel goals.
- H4. As knowledge automates, mental effort decreases and learner overconfidence is a danger.
- H5. Persistence at a learning task is a positive, linear, multiplicative function of domain self efficacy, mood and task value. Below a “control threshold”, persistence stops and an automated default focuses attention on novel goals.

An explanation for MMI features that may damage or aid learning is drawn from cognitive motivation research, specifically from expectancy-control theory and from cognitive learning theory. The purpose of the five hypotheses is to generate additional research to help explain the many kinds of mistakes and learning failures that are caused by links between motivational and learning processes. A “yin and yang” model is proposed to explain the learning failures associated with instruction in novel, declarative knowledge on the one hand and the use of more familiar, automated, procedural knowledge, on the other hand. It will be suggested that when motivational problems are encountered when learning declarative knowledge, they are caused by “yin processes” that substitute different, novel and unintended learning goals and strategies for the ones intended by MMI instructional systems. When motivation problems are encountered during procedural learning, they are caused by “yang processes” that elicit familiar, automated but unsuccessful learning goals and strategies for over confident students. Where research-based solutions are available for motivational problems, they are described.

Introduction

Instructional research is rich with studies of important learning and motivational processes that operate during complex learning (e.g. Anderson, 1993; Bandura, 1977, 1997; Bower, 1983; Gagne, E. et al., 1993; Gagne, R. and Medsker, 1996; Pintrich and Schunk, 1996). Cognitive research on the executive processes that are thought to control learning activities has provided us with the potential to improve the impact of instruction. One source of this improvement is to use the flexibility and resources of multi-media, computer-based technologies for designing and delivering instruction that compensates for student information processing and study skill deficits. Newer media provide potentially cost-effective access to a great variety of instructional simulations, formats, symbol systems, monitoring and feedback capabilities on the one hand, and information scaffolding methods that might aid cognitive processing during learning, on the other hand. Multi media instructional systems, from the viewpoint of the learner, are characterized by: a) Information rich displays where almost all visual and auditory formats and symbolic modes can be presented at once, if desired; b) the potential for high levels of real time interactivity (transactions) between the system and individual learners; and c) maximum learner control of instructional access, pacing, scheduling, feedback, and structure. Dillon and Gabbard (1998) have provided a recent review of research on the effects of various design and formatting features in “hypermedia” on learning. They define hypermedia as “...a generic term covering hypertext, multimedia and related applications involving the chunking of information into nodes that could be selected dynamically” (Dillon and Gabbard, 1998, p. 323). After reviewing studies conducted in the past decade, they came to a conclusion similar to earlier reviews by Clark (1983; 1994a, 1994b). Essentially, the evidence in multimedia and hypertext research suggests that all learning benefits from the newer media also cause learning problems for some learners. They summarize their review by suggesting that only rapid searching, learner control and accomodating learner styles occasionally help increase learning in multi-media instructional environments. They also indicate that each of these benefits can harm learning for some students.

Motivational Processes That Support Or Inhibit Complex Learning

Most reviews of instructional design for MMI environments focus on types of knowledge and strategies for knowledge acquisition and more or less ignore motivational issues. Yet, knowledge cannot be acquired and used without appropriate motivational levels (Pintrich and Schunk, 1996). Whereas knowledge provides substance and organization to behavior, motivation provides “...the process whereby goal-directed activity is instigated and sustained” (Pintrich and Schunk, 1996, p. 4). Motivation is also concerned with the amount and quality of the “mental effort” people invest in achieving goals. Mental effort is defined as “the number of non-automatic elaborations necessary to solve a problem” (Salomon, 1984, p. 231). Elaborations are

enhanced by instructional methods such as examples and analogies, the cognitive mechanisms that connect new declarative knowledge to previously learned information (E. Gagne et al, 1993). These two elements of motivation, active and sustained goal pursuit (committed persistence) on the one hand, and mental effort, on the other hand, are the primary outcomes investigated in motivation research and the primary focus of this discussion. Mental effort is the engine that provides the energy necessary to support complex learning. Complex learning is the essential ingredient of “knowledge work” that is the primary source of the products and services that support large and small business and government organizations (Caisco, 1995). Motivational studies have found that cognitive motivation accounts for between 12% (Helmke, 1987) and 38% (Fyans & Maehr, 1987) of the variance on academic learning tasks. The model presented here derives, in part, from an analysis of motivation research by Pintrich & Schunk (1996); from the Motivational Systems Theory (MST) proposed by Martin Ford (1992) and from recent work on cognitive effort by Bandura (1997) Salomon (1984) and Clark (In press, 1999) among others. It is intended to serve as an update on an older motivational design model presented by Keller (1983).

Expectancy-Control Model of Motivation to Learn and to Solve Problems

The following discussion of motivational problems that occur in complex learning environments is drawn from cognitive motivation theory, often called “expectancy-control theory”. Many motivation researchers (e.g. Freedman and Lackey, 1991; Heckhausen and Schultz, 1995; Shapiro, Schwarz and Austin, 1996) share the implicit and explicit belief that the ability to gain and maintain a sense of personal and group control or effectiveness is the essential goal of all motivated behavior. Expectancy-control researchers assume that committed behavior is rational (although not always logical or effective). Persistence at a learning or problem solving goal over time is presumed to result from an explicit or implicit analysis of the “control potential” value of achievement or learning goals. The general hypothesis that seems to underlie expectancy control theories is that the more we perceive the achievement of learning goals to bring increased control or effectiveness, the more we are motivated to persist at those goals when faced with distractions. When convinced that a learning goal will decrease our effectiveness or control, learners are less willing to continue pursuing the goal and the more inclined they are to select an alternative goal. While different individuals and cultures might adopt radically different preferred methods for achieving control, the value for control is thought to be one of the most dominant and crucial human “universals” (Brown, 1991). Evidence for the benefits of achieving and maintaining stable “control beliefs” through adequate “self regulation” (Carver and Scheier, 1998) across developmental stages (Heckhausen and Schultz, 1995) is provided in studies of academic learning and problem solving (e.g. Bandura, 1997), psychotherapy (Wegner, 1997),

and medicine (Shapiro, Schwarz and Austin, 1996; Enserink, 1999). Evidence for the destructive effects of beliefs that control has been lost or compromised have also been provided by many researchers (e.g. Peters, et al. 1998; Wegner, 1998; Shoham and Rorbacher, 1998).

What Aspects of Learning Does Motivation Support?

Pintrich and Schunk (1996) have suggested that our diverse body of current motivation research tends to focus on a number of “indexes” or outcomes. These indexes are the problems that motivation researchers are attempting to understand and solve. Examples of these outcomes are goal choice (the passive and active selection of learning or performance goals), commitment (persistence at a learning goal over time, in the face of distractions), mental effort (employing conscious, non-automatic cognitive strategies to facilitate goal achievement) and performance (measures of learning goal success). All of these indexes have, at one time or another, been used to characterize motivation to learn and to define the variables examined in motivation research. Since goal commitment and mental effort seem to be the key motivational issues in most adult learning and work settings, the theoretical model chosen for this discussion is drawn from the CANE (Commitment And Necessary Effort) model described by Clark (In press, 1999). The goal in this discussion is to provide a motivational explanation for the cognitive overload issues raised by Sweller (1999) and the destructive effects of instructional methods described by Clark (1982, 1987) and Lohman (1986). The discussion of motivational processes that operate in MMI learning environments has been divided into seven, inter-related hypotheses. Evidence for each hypothesis will be discussed in turn. Then suggestions are made for how designers in MMI environments might unintentionally cause learning problems and how design rules might avoid problems and enhance motivation to persist and invest maximum mental effort for learning goals.

Cognitive Load and Mental Effort

The discussion begins with a suggested connection between student’s perception of the cognitive load they expect and experience during learning and the amount of mental effort they invest to learn from instruction. A primary assumption supporting this discussion is that intrinsic learner perceptions of cognitive load are often more powerful than extrinsic, “objective” measures of cognitive load.

Hypothesis 1: As intrinsic cognitive load increases, mental effort increases linearly and positively

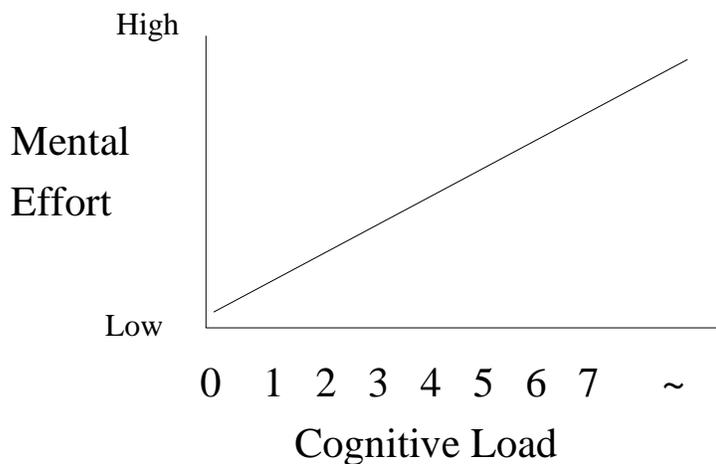


Figure 1: The hypothesized relationship between cognitive load and mental effort.

Many studies have found evidence for a direct connection between cognitive load and mental effort (Miller, 1956; Paas, 1992; Sweller, 1999). Presumably, all students continually monitor the extent of the novelty and difficulty posed by a learning goal (Pintrich and Schunk, 1996). Judgements of task difficulty appear to directly influence the amount of mental effort invested in a learning task (Salomon, 1984; Clark, 1999). Since perceived difficulty is primarily (but not entirely) a function of cognitive load, “other things being equal” we could expect a positive and linear relationship between these two variables. The more instructional elements that must be consciously manipulated by elaboration or reorganization, and the more “non automatic” cognitive strategies that must be developed to manage these cognitive manipulations, the more mental effort that must be invested to achieve learning goals. As the number of items that must be processed in working memory increase, mental effort must necessarily increase if learning is to be successful. We also know that maximum learning gains are achieved with the maximum levels of challenge a student can tolerate successfully (Locke, 1990; Locke & Latham, 1990). In order to insure that cognitive load is high enough to insure maximum learning gains but not so high as to overwhelm students, some way to measure mental effort needs to be included in instructional systems.

The Measurement of Intrinsic Cognitive Load and Mental Effort

The purpose of focusing on the relationship between load and effort is that it is difficult to

accurately measure “intrinsic” cognitive load because of the large variation between learners in prior knowledge that can be used to elaborate information resident in working memory (Sweller et al, 1998). Instead, it seems better to attempt to measure mental effort since each student’s effort will be directly related to their individual perceptions of their own cognitive load (Salomon, 1983; Pintrich and Schunk, 1996; Bandura, 1997). The measurement of effort is not yet well developed. Salmon (1983) has defined mental effort as our perception of the mental energy required to use “non automatic” knowledge to solve problems, learn or transfer knowledge to new tasks. The measurement of the use of non-automatic knowledge is not well developed (but see a review by Cennamo, 1989). Instruments currently available include a variety of post task, self-report measures (Bandura, 1997, Schwarzer, 1992); indirect estimates of latencies and time to complete tasks (for example, Dweck, 1989; Corno & Kanfer, 1993) and dual-task measures (e.g. rhythmic finger tapping while engaged in complex learning and practice; additional examples described by Cennamo, 1989). The most efficient measures are those that only require post-task, Likert-style, self-reported estimates of how “difficult” or how much “thinking” the task required. The reliability of these self report measures is often quite high (e.g. Dweck, 1989). The most robust measures seem to those associated with “dual tasks” that interrupt learners at different stages during instruction and ask them to perform an unrelated and interfering task or operation (e.g. finger tapping or solving mental mathematics problems) while they are under time pressure to complete the learning task (e.g. Peters et al. 1998). The more that the dual task performance is delayed or interrupted, the more mental effort a person is presumed to be experiencing.

Mental Effort and Self Efficacy

Mental effort is difficult to observe directly so it is necessary to search for indirect measures. Bandura (1997) and Salomon (1981, 1983, 1984) have argued that task-specific self efficacy is greatly influenced by mental effort expenditures. Presumably, the experience of mental effort influences our personal efficacy expectations about a learning task. Thus, task-specific self efficacy can be described as an important indicator of past mental effort investments and past intrinsic cognitive load experienced during the learning. The second hypothesis describes the expected shape of the relationship between mental effort and specific self efficacy (Figure 2):

Hypothesis 2: Mental effort has an inverted U relationship with task self efficacy.

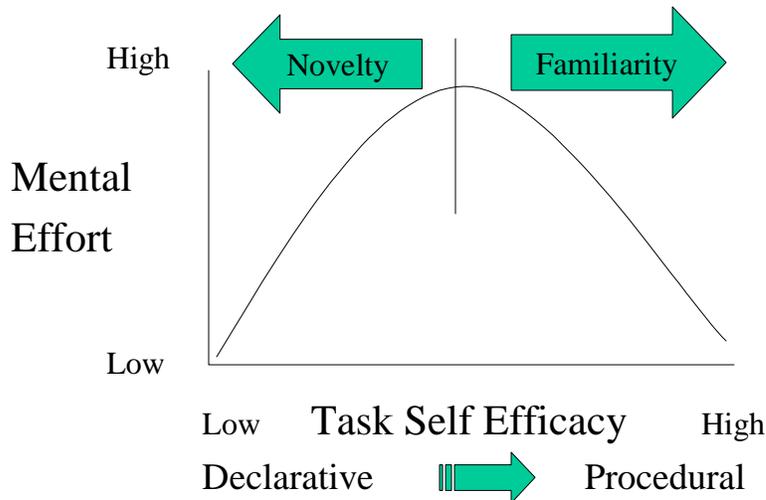


Figure 2: Mental effort has an inverted U relationship with task self efficacy so that self efficacy decreases as task novelty increases and vice versa.

Bandura (1997) has defined self efficacy as “...beliefs in one’s capabilities to organize and execute courses of action required to produce given attainments.” (p. 3). Self report measures of self efficacy have been found to be highly reliable and accurate predictors of academic achievement regardless of student ability level, prior knowledge or age (Bandura, 1997; Pajares, 1996; Pintrich & Schunk, 1996). For example, Pajares and Miller (1994) found that mathematics self efficacy was a better predictor of math achievement than was prior mathematics knowledge or the value students placed on mathematics knowledge. Bandura (1997) suggests that efficacy beliefs mediate the effects of skills on performance by influencing effort and persistence. Thus, one powerful reason for perceived self efficacy’s success in predicting academic achievement may lie in its association with mental effort. Self report measures of efficacy simply ask students to report their own assessment of the learning or problem solving “difficulty” they experienced. Since difficulty judgements are largely due to students experience of their cognitive load they experienced in past learning and problem solving tasks in a particular subject matter area, perceived self efficacy is highly predictive of current and future mental effort (Bandura, 1997; Salomon, 1981, 1984).

Evidence also exists to support claims that the more specific the set of tasks being addressed by a self efficacy questionnaire, the more robust the prediction of mental effort and

learning (Bong & Clark, In Press; Pajares & Miller, 1994). For example, Algebra self efficacy is a better predictor of mental effort invested in algebra than is mathematics self efficacy or academic self efficacy (Pajares & Miller, 1994). Bong (1997) has provided evidence that this finding is due, in large part, to the more accurate judgements of cognitive load coming from assessments of more specific tasks. She has found that students can accurately judge their self efficacy for tasks they have never performed because they assess the similarity of familiar tasks or observations of the performance of other students who they judge to be similar in experience and ability and generalize their expectations to unfamiliar but similar tasks. The larger the scope of the tasks being assessed with a self-efficacy measure, the more variation in cognitive load one would expect. Variations in load would tend to be handled by “averaging” and produce summary self-efficacy assessments that were less predictive of the amount of effort invested in any specific learning task.

Inverted U Relationship Between Self Efficacy and Mental Effort

While many studies have reported a linear and positive relationship between self efficacy and mental effort (for example, Covington, 1992), a number of motivation researchers suggest that the shape of this relationship is an “inverted U” (Salomon, 1983; Clark, In press 1999). The reason for this suggestion requires a bit of explanation. When confronting a challenging and novel learning task, self efficacy tends to be low because of the amount of conscious, declarative knowledge that must be manipulated. As learning progresses satisfactorily, declarative knowledge gradually automates and efficacy increases. As knowledge becomes more and more automated, effort decreases even though self efficacy continues to increase. The more familiar the goal and the more knowledge and skill we believe we have gained in the pursuit of similar goals, the less effort we are inclined to invest. The rationale for this relationship can be understood by reference to cognitive theories of knowledge types (e.g. Anderson, 1983, 1993; Gagne et al, 1993). Automated expertise, developed over many hundreds of hours of practice, requires no cognitive effort to express. The more that learning requires the acquisition and use of conscious, non-automatic, declarative knowledge, the more cognitive effort is required (Anderson, 1983, 1993; Salomon, 1981, 1983, 1984). The more perceived mental effort required, the lower the specific self-efficacy judgements learners assign to themselves. The more novel and difficult we perceive the goal to be, the more challenge we expect in the task and the lower our perceived self efficacy. Bandura (1997) has commented on this phenomenon and advises that the most effective learners and performers possess extremely high domain-general self efficacy but much lower short-term and specific self efficacy. The utility of this mix of self-efficacy levels seems to be to encourage the use of the greatest amount of mental effort for new learning and for the solving of novel problems.

Cognitive Overload and The Efficacy Default

From the preceding discussion, it seems reasonable to assume that the maximum amount and quality of complex learning takes place in a narrow range between too little and too much cognitive load, mental effort and self efficacy (Snow, 1977). What happens when cognitive load exceeds working memory capacity (see figure 3)? Evidence from a number of areas in psychology suggests that learners may establish an “efficacy threshold” where increasing amounts of perceived or “intrinsic” cognitive load results in a number of automated default behaviors:

Hypothesis 3: At the “Efficacy Threshold” effort stops and an automated efficacy “Default” directs attention to different goals

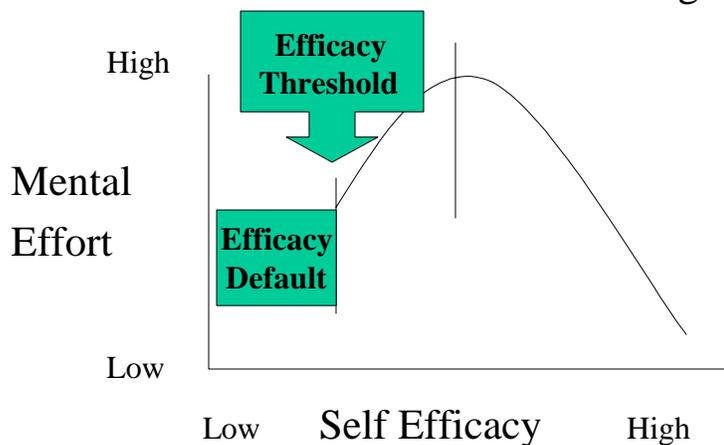


Figure 3: At the “Efficacy Threshold” effort stops and an automated cognitive “Default” directs attention to different or novel goals.

It is likely that when tasks are perceived as impossible, self efficacy issues lead us to avoid the goal at hand (Salomon, 1981, 1983, 1984; Clark, In press, 1999). This hypothesis assumes that mental effort slows then stops at either exceptionally low or high self efficacy levels. The phenomenon is implicit in the hypothesized inverted U relationship between efficacy and effort. The more novel and difficult the learning goal is perceived to be, the more effort we expend until the novelty grows beyond an efficacy threshold. Salomon (1984) for example, presented evidence that our perceptions of the difficulty of learning from various media greatly influenced perceptions about the amount of conscious, non-automatic mental elaborations required to learn

or solve problems. He found that people who believed that a medium (e.g. print) was very difficult, worked significantly harder to learn a task from that medium than they invested in the same learning task presented on another medium (video) they had judged to be much easier. He also found that people who believed that a learning task was impossible expended no effort. Instead, they reported looking for “other things to do”. There is recent evidence that when the efficacy threshold experienced during cognitive overload, an automated “default” occurs that forces learners away from the immediate learning goal and towards novel or different performance goals (e.g. mistakes that they had been trying to avoid or yielding to distractions through mental fantasy or “day dreaming” or activities available in their immediate environment such as computer games or social interaction). Snow (1977) has termed this default the “Zone of Intolerable Problemicity” (ZIP) in a parody of Vygotsky’s “Zone of proximal development”. Evidence for the ZIP reaction to increasing cognitive load can be found in a variety of research areas including studies of psychotherapy processes and cognitive load theory.

Wegner’s Ironic Monitoring System Model:

Wegner (1997) has provided evidence for a process he calls “Ironic” mechanisms in mental control. He presents evidence that when working memory is overloaded by anxiety or fears, the result is that an “ironic monitoring system” causes an automated cognitive efficacy threshold default. The monitoring system is characterized as unconscious, uninterruptable, “...searches for mental content signaling a failure to create the intended state of mind” and introduces “...different, unwelcome and unintended behavior” (p. 148). Unintended behavior can range from “slips of the tongue” (embarrassing expressions people try to avoid or thoughts that one wishes not to experience or to express publically) and extend to more complex mistakes that one may be attempting to avoid. He and his colleagues provide evidence for the impact of the ironic process on people with high levels of anxiety, depression, anger and eating disorders (Wegner, 1997). Shoham & Rohrbaugh (1997) draw on cognitive expectancy-control theory and attribute the ironic process to a perceived loss of control. They describe the downward spiral of control loss that afflicts many people who seek psychotherapy because they cannot learn to control intrusive fears, thoughts or mistakes. Initial control problems with, for example, intrusive and obsessive thoughts about mistakes or failures, encourage helpful friends and family to urge the person to “stop thinking about it”. The more a person tries not to think or worry about something negative, the more that cognitive overload occurs and unwelcome, intrusive thoughts occur in working memory. The more that these thoughts are experienced, the greater the perceived loss of control which lowers our self efficacy for control of our own thinking. The result is that the efficacy threshold widens and intrusive thoughts increase. This “cycle of despair” (Shoham & Rohrbaugh, 1997, p. 152) is described as a pattern where helpful

suggestions are offered, failure to control mistakes and intrusive thoughts when trying to implement the helpful suggestions produces an increased perception of loss of control (lowered specific self efficacy). The resulting higher failure level produces an even greater increase in the strength of “helpful suggestions” and even more dramatic failures ensue.

The ironic monitoring system is contrasted with an opposing, “intentional monitoring system” that is “...conscious, effortful and interruptible ...(and) searches for mental content consistent with the intended state of mind.” (Wegner, 1997, p. 148). This system is the one that we hope is operating when learning is taking place. It focuses attention on assigned learning goals and activities and encourages the retrieval and reorganization of appropriate prior knowledge schema’s. In order to maintain the intentional system, students must, at all times, believe that they are experiencing a personally manageable level of novelty and difficulty in instructional displays.

Sarbin’s Strategic Action Model:

A process similar to the ironic and intentional systems has been proposed by Sarbin (1997) who describes cognitive reactions to events that conflict with our self efficacy. Sarbin suggests that monitoring processes are sensitive to efficacy conflicts in the form of hostility, extreme difficulty, novelty and unexpected events. When learning goals focus attention on more novel, declarative and complex information, efficacy conflicts are more likely. Metacognitive processes map internal and external events containing efficacy conflicts that violate expectations, beliefs and values in order to determine how much and what kind of mental and physical effort is required to handle the conflict. Conflict results in strategic actions of various types that are designed to reduce the conflict and achieve a social confirmation of the result. Sarbin’s system provides a much richer array of reactions to efficacy problems than the Wegner ironic default theory. Sarbin (1997) describes five types of strategic action that are deployed by most people to handle threats to efficacy: 1) Instrumental acts that seek to change the external environment through “fight or flight”, ritual acts (such as prayer) or “letters to the editor of newspapers”; 2) Tranquilizing and Releasing Acts that attempt to change internal states through acts such as their use of narcotic drugs, physical exercise, compulsive gambling and sex; 3) Attention development that focuses attention on consistent input (to balance the conflict) through neurotic behaviors such as conversion reactions, imaginary worlds; hypochondriasis, or projection; 4) Changing beliefs and values that attempt to modify perceptions of the event so that the new perception disconfirms the threat or conflict such as “reframing” or “reinterpreting” the event; and 5) Escape behaviors such as depression, helplessness and quitting or dropping out. Each of these reaction strategies have alternatives that are helpful (reframing the event) and those that are potentially harmful (narcotic drug use) and destructive. The alternatives that are more helpful

seem to be learned over time whereas many of the more destructive alternatives may be in the form of automated procedural knowledge. It is also interesting that some of Sarbin's 5 strategies involve changing the environment (Instrumental Acts), others involve changing the self (Changing Beliefs) and some involve avoiding the problem (Tranquilizing and Releasing, Attention development, and Escape). Sarbin's (1997) suggestion of internal and external strategies connect nicely with the developmental theory of motivation suggested by Heckhausen and Schultz (1995). They offer evidence that younger people tend to choose "primary" or external strategies when faced with negative feedback about their performance under conditions of excessive challenge or conflict, whereas adults tend to select more "secondary" and internal strategies in the same context. It is also likely that with both internal and external strategies, the more destructive reactions to conflict or efficacy challenges come from people with overloaded working memory. When working memory is exceeded, the more recently learned (and presumably more effective and less destructive) strategies will be inhibited in favor of the older (childish?) and more automatic and destructive alternatives. This is the essence of the Ironic default.

Learning Failures Due to Consistency Checking, Feedback, Split Attention and Redundancy:

In addition to the ironic and agency models, Vosniadou et al (1988) describe studies in prose learning where cognitive overload during consistency checking of propositions in prose stories produces a default that increases errors. Students who were overloaded failed to note that new propositions in prose stores were similar to those already encountered and so incorrectly classified them as new and different. This knowledge-based default seems to cause a cognitive reversion to previously learned and more automated but more general and less effective propositions.

Kluger and DiNisi (1998) describe feedback interventions that reduce or prevent learning. Presumably, learning progress feedback influences learning because it focuses student's attention on the gap between current knowledge and learning goals (Kluger and DiNisi, 1996). Feedback that focuses attention on a learner's mistakes or that encourages a comparative ranking of learners appears to often result in efficacy defaults. Corrective feedback (emphasizing mistakes and the avoidance of mistakes) may often unintentionally result in an efficacy default and the operation of the ironic process. In this scenario, corrective feedback would actually "suggest" or "enable" mistakes and a sense of helplessness in students who were trying to avoid those mistakes. This scenario seems to reflect Wegner's (1997) ironic default and Sarbin's (1997) Attention Development where learners attempt to do what is consistent with the immediate content of cognition. If fear of mistakes is current in working memory, then committing mistakes brings the cognitive system back into balance and eliminates conflict. Kluger and DiNisi (1998)

argue that feedback emphasizing the gap between current learning progress and intended learning goals is much more successful in directing mental effort to relevant learning problems and preventing efficacy defaults. Students experiencing efficacy defaults could be called “under confident”. It appears that under confident may benefit from reassurance that the learning task can be made more manageable, by reducing cognitive load. One way to reduce load is to divide a larger task into a series of smaller, more specific and tractable tasks (Clark, In press 1999).

Split Attention and Redundancy Effects:

Sweller (1999) describes two types of instructional conditions that often cause students to exceed the limitations on their working memory. The split-attention effect “occurs when learners are faced with multiple sources of information that must be integrated before they can be understood” (p. 22). This effect often occurs when graphic displays and their verbal “explanation” are separated from each other and when neither source of information can “stand alone” and so both sources must be considered together in order for effective learning to occur. The mental effort required to integrate graphic and text components of a display can overload working memory and contribute to an efficacy threshold default. A related phenomenon called the “redundancy effect” occurs when both textual and graphic material on some topic are redundant. Sweller (1999) presents evidence that when students attempt to master the redundant graphic and text information the effort results in an unnecessary and sometimes negative effect on the cognitive load in working memory. Presumably, students invest unnecessary mental effort to integrate redundant messages. It may also be the case that when integration of the redundant messages fails (as it must because no integration is possible) students perception of failure enhances the violation of the efficacy threshold. The split-attention effect can be eliminated if graphic and verbal information on a topic are fully integrated. The redundancy effect can be eliminated if instructional displays provide only one form of information about a topic (or two fully integrated forms). It would be interesting to investigate the nature of the working memory failures caused by overloading working memory with the split-attention or redundancy effect. Cognitive motivation theory would suggest that overloaded learners in these two conditions would default to focusing on different or novel learning goals (or non learning goals).

Yin and Yang Processes

Attempts to explain learning failures caused by perceptions of working memory overload suggest that dual metacognitive monitoring processes operate during learning. Each of these processes searches for different, opposing conditions. They are, in the terms of Chinese philosophy, a balanced “Yin and Yang” duality. This second century feature of Taoist thought, hypothesized a duality in nature where all important forces manifest themselves through

opposition. The opposing Yin “difference” processes come into play when working memory is overloaded or is perceived to be overloaded. Yin processes express themselves most often during the learning of novel, different, declarative knowledge. Yin processes are characterized in part by the “ironic” monitoring system described by Wegner (1997). This aspect of metacognition is more automated and it searches for evidence of failure and other “different” and feared results in working memory when learning complex declarative knowledge. Wegner (1997) suggests that the ironic monitoring system “tests whether the operating process is needed by searching for mental contents inconsistent with the intended state” (p. 34). When working memory is overloaded and self efficacy falls below a threshold, the monitoring process is not able to call up previously learned coping behaviors and a default forces the expression of unintended behaviors including self-defeating activities (such as mistakes one is trying to avoid or thoughts of escape from the failure situation) that are the subject of anxious concerns faced by many students. The effect of Yin processes is to focus attention and elaborative activity on different, inconsistent and unintended goals and connections in working memory and long term declarative memory.

Yang effects are associated with “similarity” processes and events during the reorganization, modification and extension of procedural knowledge. Learning is facilitated by drawing on previously learned procedural knowledge in the form of discrete “similarity” associations supported by “spreading activation” (Anderson, 1993) and other “flow of control” based learning and performance processes (Anderson, 1983; 1990; E. Gagne, 1993) tend to be used more when learning or problem solving requires the use or practice of procedural knowledge. Yang activities are evaluated by the “intentional monitoring system” described by Wegner (1997) and they facilitate conscious, effortful attention to goal-compatible knowledge in long term memory that are similar to intended learning goals.

Sarbin’s (1997) strategic action model begins with the same events as Wegner’s. As cognition moves more toward the declarative “Yin” side, barriers to goals tend to become more novel, unexpected, and difficult to overcome. This kind of experience produces more internal conflict and threat so people select (or default to) strategies that attempt to reduce the resulting conflict and difficulty. As efficacy is threatened, a number of learned and automated strategies might be employed by learners. Each of Sarbin’s strategic action types seem to have variations that are more productive, while others seem more destructive. Some of those strategies seem to emphasize habit and automated reactions to difficulty and danger (for example, fight or flight, narcotic drugs, neurotic projection) and some emphasize more helpful learned strategies (for example, reframing, letters to the editor of newspapers, exercise, seeking out other views of events).

Ordinarily, the Yin and Yang processes collaborate effectively to both foster intended

learning behaviors and to avoid unintended activities. When students perceive that the learning goal they are pursuing is impossible (because of cognitive overload or a misunderstanding of events), the efficacy default can take many forms. The most destructive forms of the efficacy default seem to occur when working memory is overloaded and more helpful coping strategies are unavailable because their expression requires working memory space (see Figure 4).

Below a control threshold, persistence stops and an automated control default focuses attention on goals with more control potential

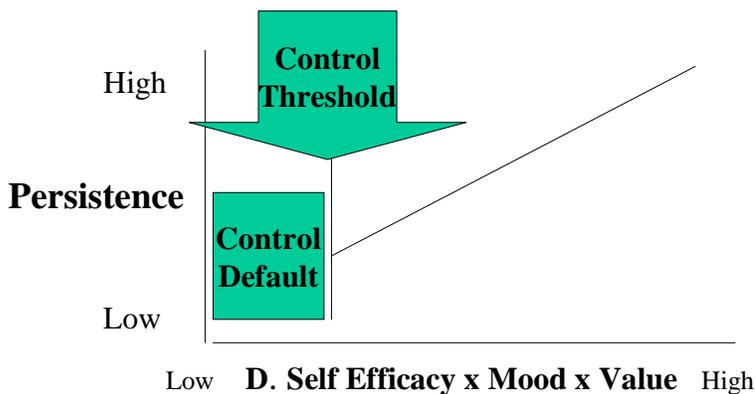


Figure 4: Efficacy/Control Default Threshold

Efficacy Threshold Summary:

When a learning or problem solving task is perceived as excessively novel and difficult, and/or maximum cognitive load is exceeded, a learner’s efficacy threshold is violated. The result is an automated “efficacy default” where either lowered task self efficacy or, in extreme cases, helplessness is experienced. Under default conditions, learning and problem solving goals are abandoned in favor of either new goals or the operation of an automated monitoring system that searches out and expresses anything that learners have been trying to avoid including feared mistakes, distracting thoughts or goals and inadequate learning strategies . It is important to note that the “efficacy threshold” default is both automated and that it focuses attention on new or different goals, thoughts and strategies that distract learners from intended learning goals. The positive but opposite system is learned, conscious and focuses attention on information that is similar or compatible with resident learning goals. These “Yin and Yang” opposing cognitive systems are hypothesized to moderate the interaction between the conscious, learned, positive and helpful similarity or compatibility functions that function in the learning of declarative

knowledge on the one hand, and the unconscious, automated, negative and hurtful novelty processes that support the learning of procedural knowledge, on the other hand.

Mental Effort Problems Not Caused by Motivational Processes

While many learning problems seem to be caused by the efficacy consequences of very difficult and novel learning tasks, motivation problems are not the only cause of depressed learning outcomes. Efficacy defaults seem most often to happen to anxious, inexperienced learners. The less experienced and more anxious students seem to be the most vulnerable to learning problems. Yet, Clark (1982, 1989) and Lohman (1986) have presented evidence from aptitude-treatment interaction studies that certain attempts to help anxious and lower prior knowledge students can cause learning and motivation deficits for the highest ability students. It appears that when instructional designers include instruction in learning strategies along with instructional information for all learners, more experienced and able learners often suffer as a result. More experienced learners apparently attempt to make use of new learning strategies and in doing so, interfere with the use of their own previously automated, effective learning strategies that serve similar purpose. This was the case in a study by Salomon (1974) where high verbal ability subjects had their performance depressed significantly below untreated controls by a treatment that helped them actively manipulate the unfolding of three dimensional objects into two dimensions. Evidence was presented that high verbal subjects had automated the verbal translation and manipulation of spatial information. Attempts to get these high verbal subjects to use muscular-spatial manipulation strategies depressed performance on delayed post tests significantly lower than untreated control groups because of the interference of their already automated verbal strategies. In these studies, task demands that are perceived as similar to previously experienced conditions elicit automated cognitive strategies that inhibit the learning of novel procedures for cognitive processing. It is notable that in the Salomon study, the higher the verbal ability, the more that spatial rotation performance was depressed by this novel method of depicting the unfolding task. Lohman (1986) argued that: "...with extensive practice, learners become increasingly dissimilar in the cognitive structures they assemble, thus rendering a common instructional treatment less useful for an increasingly larger proportion of subjects... According to this hypothesis, then, direct instruction of cognitive skills is more likely to be successful for those who have not already developed and tuned a substantial body of procedural knowledge in the domain of interest." (p. 198).

Over Confident Mistakes When Using Automated Knowledge

The discussion turns next to problems caused not by a lack of efficacy but instead by too much efficacy in the face of mistakes during learning and problem solving. In this instance, learners continue to work at learning but make mistakes and do not take responsibility for their mistakes because they are overconfident.

Hypothesis 4: After knowledge automates, mental effort decreases and a learner overconfidence default is a danger

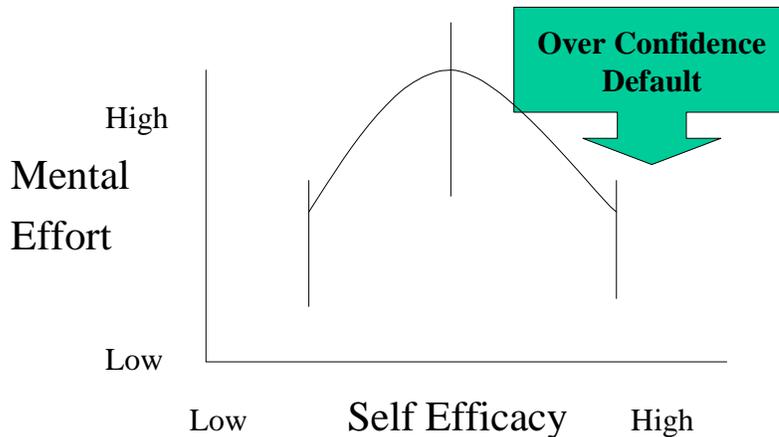


Figure 5: As knowledge automates, mental effort decreases and overconfidence is a danger.

One indicator of learning problems caused by too much efficacy occur when people with adequate prior knowledge are making mistakes on a task they are actively pursuing (if people are avoiding a task, they have a commitment or persistence problem). Once actively involved in a task, excessive efficacy (over confidence) problems show up as mistakes due to inappropriate approaches to a learning or problem solving goal. Bandura (1997) notes that these errors “arise from misjudgements of personal efficacy rather than from performance ambiguities or constraints” (p. 70). He suggests that when people select plans and strategies to handle learning (and other) goals, they based their decisions, in part, on their past performance in goals situations that they judge to be similar. Since similarity judgements can be misleading, experienced learners may apply previously automated learning strategies that they believe to be appropriate when, in fact, the strategy is causing them to make mistakes. Bandura (1997) suggests that the optimum self efficacy for specific learning tasks should be on the moderate to low side (to promote the maximum use of mindful mental effort) and moderate to high for the larger domain of knowledge represented by the task (to promote persistence and commitment to learning goals).

Yates et. al, (1998) describe a series of studies designed to assess the effects of overconfidence in self assessment of knowledge and strategies. In general, they conclude that “... people’s probability judgements about their general knowledge are higher than the proportion of

questions they actually answer correctly.” (p. 91). This overconfidence finding seem to hold true for a great variety of cultures and nations (except for Japan and Singapore). Yates et al (1998) also noted that in most experiments where a “cost” is assigned to wrong judgements about one’s knowledge, overconfidence tends to disappear. Presumably, when wrong judgements are perceived to damage efficacy, overconfidence decreases. There is recent and compelling evidence that when general (domain) self efficacy is slightly higher than is warranted, emotional well being is enhanced (see for example the discussion in Bandura, 1997). However, the proportion of students who use familiar and automated learning strategies when new or modified strategies need to be developed may be severely underestimated as a source of errors during instruction. If these students have the capability to generate the new learning strategies that are required, and if overconfidence leads them to reject responsibility for the errors they make, the problem can be very damaging. This may have been the case in the analysis of displacement errors by Ohlsson (1996).

Automated Displacement Models

Instead of mistakes caused by efficacy defaults and novelty seeking, displacement models suggest that earlier, more automated but incorrect knowledge and strategies interfere with the learning of new and often more specific knowledge. Ohlsson (1996) has described a displacement model that describes the origin and correction of common mistakes made during concept learning. He suggests that “similarity checking” is a critical element in most new learning. When learning a concept, students must develop schemas containing a set of attributes that define the concept. Mammals, for example, are defined as hairy, warm blooded animals who give birth to live young who are suckled. When practicing the learning of new concept definitions, students are asked to classify a set of examples and non examples. Learners must try to select examples that contain the defining attributes of the target concepts. For example, when presented with examples of animals such as “dog, cat, bird, horse, whale, shark”, students are expected to identify hawks and sharks as “non mammals” because they do not have all of the defining features. When self efficacy is extremely high it is more likely that learners will displace the new classification knowledge in favor of older, more familiar, more automated and often more general knowledge. The result, in terms of the example above, is that knowledge acquired previous to the current lesson will suggest that “whales” are examples of fish. Many children learn early that everything that swims is a “fish” and so incorrectly use this earlier knowledge in an overconfident way (Farrington, 1997). Dougherty et. al. (1999) describe processes in memory that support “likelihood” judgements necessary to support concept learning. Their MINERVA-DM model accounts for many of the errors that students seem to make when judging the similarity of current task demands and familiar, task-specific knowledge

and strategies already resident in memory. They make the point that these judgements can be made without the benefit of higher cognitive processes and therefore may be prone to many different kinds of error that contribute to overconfidence.

Perkin's "Disrationalia" Defaults:

Perkins and Grotzer (1997) described a number of behaviors that seem to stem from "...the pattern driven character of cognition as well as ego defense and other mechanisms" (p. 1125). They describe four default tendencies including learning strategies that are "Hasty (impulsive, insufficient investment in deep processing and examining alternatives); Narrow (failure to challenge assumptions, examine other points of view), Fuzzy (careless, imprecise...); and Sprawling (generally disorganized, failure to advance or conclude)." (Perkins and Grotzer, 1997, p. 1125). They advise instructional designers and teachers to emphasize domain and task specific strategies that help students toward more reflective, strategic, and self monitoring in their approach to learning tasks.

Seductive Details

The destructive effects of overconfidence may be one of the factors that cause the seductive detail effect described by researchers such as Harp and Mayer (1998). In a series of studies, Harp and Mayer (1998) inserted irrelevant information into lessons about natural processes such as lightening. Learning goals required students to recall details and solve problems using their knowledge of factors and processes that cause lightening. Instructional displays provided the information necessary to learn but some treatments also included engaging but irrelevant information such as pictures of buildings, trees and people who had been struck by lightening and pictures of people in situations where they were exposed to danger from lightening. When seductive details were available, learning was depressed. All learners finished the lessons within the same time limits despite the presence of irrelevant and seductive details in experimental groups. One interesting feature of the Harp and Mayer (1997) studies was their attempt to determine the exact cause of the depressed learning based on previous hypotheses. For example, they found that placing the seductive details earlier in a lesson caused significantly more learning problems than when the same details occurred later in lessons. They concluded that seductive details cause students to generate inaccurate learning goals. As a result of the inaccurate goals, the students searched long term memory for irrelevant knowledge and constructed knowledge schemas that were not helpful. The effort spent to form schemas based on irrelevant information "diverts" attention away from intended goals and thus learning is depressed. While Harp and Mayer (1997) did not measure learner confidence or efficacy, we could assume that those who received seductive details were confident that the new (and irrelevant) learning goals

they generated were useful.

To this point, the discussion has focused on the motivational processes that lead to changes in mental effort. However, there are other motivational outcomes that are influenced by motivation. Pintrich and Schunk (1995, see chapter 2) describe these outcome variables or “indexes”. In addition to mental effort, commitment or persistence is a very important outcome variable. The discussion turns next to persistence problems in complex MMI learning environments.

Motivational Variables Supporting Persistence At Learning Tasks

While many researchers have examined the variables that influence task choice and commitment (e.g. Bandura, 1997; Dweck & Leggett, 1988; Erez & Earley, 1993; Keller, 1987; Locke, 1990; Locke & Latham, 1990; Schwarzer, 1993) Martin Ford’s (1992) Motivational Systems Theory provides the most comprehensive and coherent view of the factors that influence task persistence for adults during complex learning tasks. Commitment is defined in many studies as persistence at a task over time in the face of distractions. As a result of his analysis of 32 motivational theories and related research Ford (1992) indicates that there are three variables which, if taken together, appear to offer the best prediction of the strength of our persistence during learning, problem solving and other performance goals. The three variables influencing goal persistence are: 1) goal value (as we strengthen our belief that achievement of a learning goal will increase our personal control or effectiveness, our persistence at the goal is hypothesized to increase); 2) mood or emotions (positive emotions facilitate persistence and negative emotions discourage persistence); and 3) personal agency (beliefs concerning the extent to which our ability and contextual factors will facilitate goal achievement - as our expected chances for success increase, goal persistence is also hypothesized to increase).

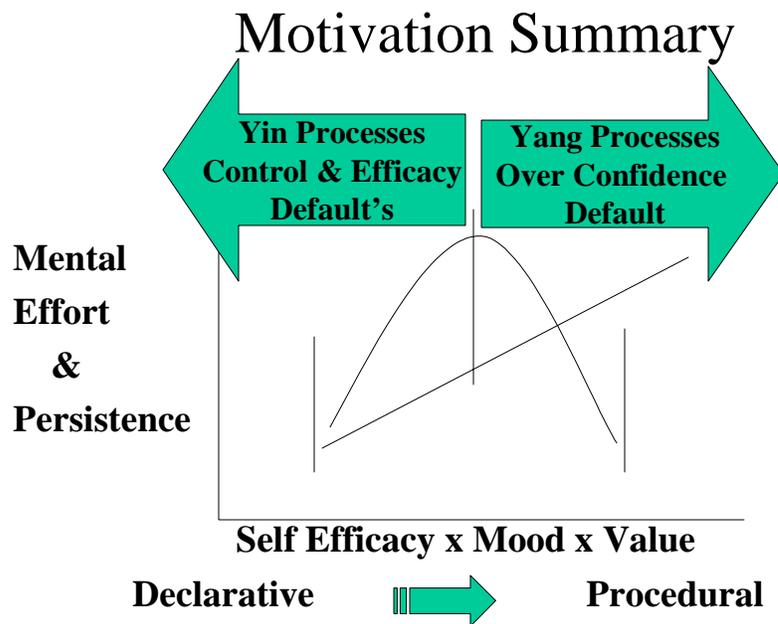


Figure 6: Persistence at a learning task is a positive, linear, multiplicative function of domain self efficacy, mood and task value. Below a control threshold, persistence stops and an automated default focuses attention on divergent goals with more control potential

The hypothesized relationship between the three variables is multiplicative. This implies that if the value of any one of the variables reaches a threshold level, goal persistence stops. When persistence stops, an automated “control default” is hypothesized to direct attention to novel goals that hold more control potential. In this discussion, each variable will be described in turn by focusing first on evidence for its negative influence on persistence, its measurement and then on interventions that have been found to increase its positive effects on persistence. It will be argued that as values for the task, positive mood and agency increase, persistence at a task will also increase. However, when either control value, mood or agency fall below a threshold level, persistence stops and another destructive cognitive default takes over and redirects attention to novel goals.

Control Values and Persistence

Some of the best and most recent research on learning goal value has been conducted by Eccles and Wigfield (1995) who have found compelling evidence for the impact of three different types of control values on persistence in educational settings. The three types are: utility, interest, and importance values for learning or problem solving tasks. The first type of value, utility, is

defined as the “usefulness of the task for individuals in terms of their future goals, including career goals...[and] is related more to the ends in the means-ends analysis of a task” (Pintrich & Schunk, 1996, p. 295). This implies that utility value is placed on goal outcomes or ends, but not on the means or process used to achieve the outcome. Utility value is the one used to justify a less desirable experience that is endured in order to achieve a more desirable end or result. The second type of value, interest, is defined as the enjoyment or intrinsic curiosity people experience when performing tasks that have subjective interest. The third type, importance, or attainment value, represents the significance to a person of doing well on a task because success confirms their own beliefs about themselves and their skills. Importance value might sustain persistence at a goal when a learner believed that the goal represented a challenge in an area of their own special skill or aptitude. All three of these types of values contribute to our estimate of the control potential of goal persistence. Eccles and Wigfield (1995) summarize tests of these value types by confirmatory factor analysis and their relationship to goal persistence in a number of studies.

Choosing or Assigning Learning Goals. An issue related to control values concerns recent “learner control” and “constructivist” strategies embedded in instructional systems (e.g. Johanson, 1991 Merrill, 1991). Arguments about the utility of allowing learners to “explore” or “discover” learning goals and content have raged for a century. Recent versions of this argument by constructivist theories (Jonassen, 1991) suggest that only a high amount of learner control is effective in promoting individual learning benefits. Since most instructional systems cannot allow students to choose their own learning goals, will assigned or “forced” learning goals reduce persistence as suggested by Jonassen (1991)? Locke and Latham’s (1990) studies have provided evidence that people do not have to participate in goal setting in order to make a strong commitment to assigned goals. In cases where participatory goal setting is not possible, they find that value for the goal is enhanced if people perceive the goal to be: 1) assigned by a legitimate, trusted authority with an “inspiring vision” that reflects a “convincing rationale” for the goal, and who; 2) provides expectation of outstanding performance and who gives; 3) “ownership” to individuals and teams for accomplishments; 4) expresses appropriate confidence in individual and team capabilities while; 5) providing task-focused feedback on progress that includes supportive but corrective suggestions for mistakes. There is some evidence that while discovery or learner control over some goals is valuable for experts or advanced learners, those with lower prior knowledge encounter major learning problems with this instructional strategy (Merrill, 1991; Clark, 1982, 1989). This problem comes in the form of a control value default where automated yin processes dominate cognition.

Emotion and Goal Persistence

In addition to values, the current emotional state of an individual or group is also

hypothesized to influence task commitment. The general hypothesis resulting from research on emotion and commitment suggests that as mood becomes more positive, persistence becomes more likely, frequent and stronger in the face of distractions and vice versa (Ford, 1992; Bower, 1995; Boekaerts, 1993). Negative moods are characterized as sadness, fear, depression and anger (Ford, 1992). These negative mood states inhibit commitment (Bower, 1995). Positive moods are characterized by happiness, joy, contentment and optimism. Positive emotions have been found to foster commitment (Ford, 1992; Bower, 1995). In research, mood states are indicated by people's memory for information congruent with their self-reported mood state; ratings of the enjoyableness of mood congruent information or commitments; affiliation preferences for people with similar mood states; social comparisons with mood-congruent people at work; and a focus on the positive or negative aspects of goals as moods change (Bower, 1995). Expectancy-control theorists suggest that negative mood states lead to lowered expectations that success or control will be achieved by a work goal and negative moods focus people on past errors and failures (Boekaerts, 1993; Bower, 1995). In fact, there are suggestions (for example, Shapiro et. al, 1996; Weiner, 1986) that one of the origins of negative emotions is the perception that we are denied adequate control in specific situations. For example, Weiner, (1986) suggests that depression sometimes results from the self perception that we are lacking in critical skills or ability to achieve a necessary goal, and that anger is the emotional product of the cognitive belief that some external agent has threatened our self control.

Izard (1993) has presented evidence of four separate mechanisms that generate the same emotion in any individual. Only one of those systems is cognitive and under the control of the individual. Other, non-cognitive emotion activation systems include habitual or automated emotional reactions to events (Anderson, 1990, 1993) plus neural, biochemical and hormonal processes (Izard, 1993). This research suggests that the origins of emotions are not always under our direct control. Yet Bower (1995) makes the point that emotions can be influenced by environmental and cognitive events even when their origins are biological or neurological. This claim seems to be supported by recent evidence concerning the extent of the placebo effect in mood disorders such as depression. For example, Enserink (1999) reviews the meta analyses of anti depressant drug trials and concludes that seventy-five percent of the effects of new drugs such as prozak are due to expectancy beliefs and not to biological factors.

Mood Problems: Hot/Cool System Model

A different source of evidence for a mood-related "control threshold" default comes from a recent theory suggested by Metcalfe and Mischel (1999) to explain failures in volition, self control and the delay of gratification in children and adults. They hypothesize a "hot/cool system... that enables – and undermines – self control or 'willpower' ... essential to the execution of difficult to achieve intentions" (Metcalfe & Mischel, 1999, p. 3). The "...hot emotional system

is specialized for quick emotional processing and responding on the basis of unconditional or conditional trigger features... (and) deals with the kinds of automatic responses to both appetitive and fear producing unconditioned stimuli and their learned associates ... that have been relatively neglected in studies of human cognition.” (italics in original text, Metcalfe and Mischel, 1999, p. 6). When the hot system is activated by strong, negative emotions such as those accompanying cognitive overload, the result is “...a range of self-defeating and self-destructive behaviors such as impulsivity and failures of self-control, irrational fears, and addictions of many sorts” (p. 16). The cognitive default that results directs learners attention and persistence away from the goals and intentions at hand and toward different and often self-defeating goals or behaviors. Metcalfe & Michel (1999) hypothesize that automated cognitive defaults result from environmentally enabled but inherited predispositions that are more or less present at birth. Recent studies reported in Science (Bower, 1999) following new “dynamic systems models” of skill development in children provide support for the argument that novelty seeking is an early (3 to 6 month) default when food or other reasons for exploration are not fulfilled. These defaults tend to moderate over time but when anxiety or negative emotions reach a peak, and/or working memory is overloaded, an automated Yin default, often involving a search for different or novel goals, is the result.

Emotion Measurement and Intervention:

Bower (1995) describes a number of techniques for assessing emotional state and levels in research that could be adopted to MMI systems including: affiliation preferences (students report preferring to affiliate with people who share the same emotional state); recall of information related to our mood state (people tend to remember more information congruent with their current mood state); and the time spent looking, listening and reading information related to mood state (more time is spent attending to mood congruent information). The assessment of changing moods may be possible by noticing when people compare themselves with people who’s mood is more positive (if they are moving toward a negative mood) or with people who’s mood is negative (if they are shifting to more positive moods). This “reversed” social comparison process seems to accentuate the direction in which mood is moving by increasing the differences between ourselves and others whose mood is different. Boekaerts (1993) reminds us that self report measures of “stress” can also be used to evaluate negative emotion related performance problems.

Interventions that have been found to change negative mood states have included listening to music that is perceived to be positive; writing or telling about a positive mood-related experience; watching a movie or listening to stories that emphasize positive mood states (Bower, 1995); and emotion control training through “environmental control strategies”

including the choice of learning context and “positive self talk” (Corno and Kanfer, 1993). There are also indications that trusted enthusiastic, positive, energetic teachers and learner “models” encourage positive emotions in others and support learning goal persistence (Bandura, 1997).

Personal Agency and Goal Persistence

In addition to values and mood, the final factor found to influence active persistence is our personal agency beliefs. Personal agency consists of two concerns: first, Ford (1992) provides evidence that we engage in a “domain” (general) self efficacy analysis of whether we have the knowledge required to achieve the goal (“Can I do it?”), and second, we consider the barriers to our performance in the goal setting (“Will I be permitted to do it?”). The more that we believe we might be able and permitted to achieve a learning or problem solving goal, the more likely we are to choose and commit ourselves to the goal. The self efficacy “can I do it?” question engages our memory about our ability and prior experience with similar learning goals. This review seems often to be implemented at a general and shallow level during this stage in the motivational process (Ford, 1992). Bandura (1997) refers to a more general self efficacy that projects our perceived self confidence for a class of tasks based on our interpretations of our past experience. He contrasts this domain self efficacy with the very task-specific efficacy that is based on immediate experience and that influences persistence at a learning goal. He clearly recommends that domain efficacy should be high (to promote goal commitment and persistence) but that specific self efficacy should be lower (to maximize mental effort).

The mechanism for the analysis of the general, domain self efficacy component of agency may be similar to our “meta memory” or “feeling of knowing” experiences (Nelson, 1988) found in the familiar experience of “knowing that I know a fact (for example, a person’s name) without at the moment being able to remember the fact that I want to recall”. Self efficacy analysis for persistence is similar to memory analysis in that we guess whether we have capability to achieve a goal without deeply analyzing our self efficacy or the exact knowledge and expertise demands of the goal we are considering. While it seems that many people may slightly overestimate their ability to achieve a goal (Nelson, 1988, Yates et al, 1998), the errors that are made in personal agency judgements tend to occur when learners confuse their familiarity with the goal statement with their ability to achieve the goal (Reder & Ritter, 1992).

Interventions Fostering Personal Agency and Persistence

Personal agency involves both our memory of past performance on task domains similar to those we are considering and beliefs about the support available in the environment where the goal is pursued. Most measures of personal agency are based on self report (Ford, 1992). Locke (1990) and Locke and Latham (1990) suggest that goal persistence increases, and temporary failure or negative feedback is handled much more successfully, when we believe that: 1) the goal is possible to achieve within the time and resources available; 2) we have the knowledge to

achieve the goal; 3) more specific, explicit and difficult goals are chosen; 4) newly learned skills are directly relevant to goal achievement; and, 5) learning “help” and support are available. Bandura (1997) recommends three types of agency interventions: First, we should provide mastery-oriented training experiences where increasingly challenging tasks representing large goals are accomplished. This intervention requires that we have analyzed the prior knowledge necessary to achieve learning goals. In addition, Bandura recommends that learning support systems focus feedback on task success on ability and effort and feedback about failure on task goals and away from the learner. For example, when people succeed at learning goals, the best feedback suggests that the person invested “good effort” and that they “have an ability for this kind of task”. When learning difficulties occur, mistakes and failures should be attributed to external, goal related causes.

Another way of fostering personal agency at work is to expose people who make many mistakes to “coping models” (Bandura, 1997) who are perceived to be from similar backgrounds and who have selected difficult goals and are succeeding only gradually and with difficulty. This approach is most important for people who may have different cultural origins than the majority of the learners served by an instructional system. Finally, Bandura stresses the need to discourage people from using self-defeating biases as they appraise their own capabilities. He recommends an approach described by Goldfried and Robbins (1982) where people learn to modify their standards of self evaluation and personal appraisals of their efficacy. Taylor et al. (1998) suggest a specific series of visualization strategies that help people cope with control or efficacy deficit problems. They suggest teaching learners to create a series of visual images and “self talk” explanations of events, including: 1) visualize themselves at the computer screen in a state of frustration, helplessness, fear and anxiety; 2) visualize and verbally describe the steps and stages in the process of achieving learning goals (a concrete procedure for learning should be taught); 3) visualize possible distractions, interruptions and problems experienced while studying and imagine how each can be overcome. Their studies demonstrate a 66 percent greater increase in successful goal completion for students who used their visualization and coping strategies (Taylor et al. 1998).

Context Barriers and Goal Persistence

Context beliefs are another key aspect of personal agency. Commitments are also based on beliefs about the contextual barriers in the environment where the goal is pursued or where knowledge will be transferred and used. People who believe that personal prejudice, policy or procedural barriers exist in the performance environment are reluctant to make a commitment to learning goals. Ford (1992) suggests that components of the instruction must reassure students that they will be encouraged to use the skills they have learned and that no unfair or unusual barriers to the use of the knowledge exist in the application environment.

Summary and Conclusions

Multimedia Instructional (MMI) technology provides a number of exciting benefits to the many challenges facing educators interested in fostering efficient and effective complex learning. This new technology makes it possible to present a dazzling variety of information rich displays where almost all visual and auditory formats and symbolic modes can be presented at once, if desired. In addition, they bring the potential for high levels of real time interactivity (transactions) between the system and individual learners and the possibility of maximum learner control of instructional access, pacing, scheduling, feedback, and structure. Yet these new information options can also present increased opportunities to damage learning and discourage learners. In order to maximize the positive potential of MMI and reduce its potential danger, it is suggested that MMI designers incorporate cognitive motivation research into the instructional design, delivery and evaluation process. Excellent design systems for complex learning are incomplete without key motivational components. The suggestion is made that designers should monitor two essential “indexes” of motivation (Pintrich and Schunk, 1996), mental effort and persistence. Mental effort is characterized as amount of energy invested in the conscious, deliberate and cognitive elaborative processing required to learn novel declarative knowledge. Persistence is described as the extent to which students “stick at” a learning task over time and in the face of external or internal distractions.

In previous research, mental effort has been found to be correlated with cognitive load and task-specific self efficacy. It is argued that the relationship between efficacy and mental effort takes the form of an inverted U. This relationship is complex because there is evidence that at the upper and lower limits of self efficacy, all effort stops and learning problems can occur. Evidence from a variety of research traditions is presented to describe the nature of efficacy defaults, including Wegner’s (1997) “ironic monitoring system” and Sarbin’s “strategic action system and studies by Sweller (1999), suggesting that as learning tasks become more novel and declarative and cognitive load increases, an “efficacy default” can occur. In an efficacy default state, learners express more automated, unintended, feared and destructive behaviors and/or drop out of the MMI system. When efficacy defaults are experienced many times, a state of helplessness may occur for lower ability, less experienced, more anxious and more vulnerable learners.

On the other side of the efficacy continuum, as procedural knowledge is learned and automated, self efficacy often increases to its maximum and an “overconfident” default may occur. Evidence for the overconfidence default is presented from research by, for example, Ohlsson (1996) on displacement errors, Perkins and Grotzer’s (1997) “Disrationalia default”, and Harp and Meyer’s (1998) “seductive details” research. In an overconfident state, learners may misjudge learning goals, use wrong learning strategies, make mistakes and refuse to take

responsibility for their mistakes and reject corrective feedback.

In addition to the toxic defaults that accompany very high or very low efficacy, a “control default” discourages learners from persisting at MMI learning goals over time and in the face of distractions. Mental effort can be adequate yet learning can be damaged if students fail to persist by withdrawing or procrastinating. Ford’s (1992) Motivational System’s Theory is used to describe the three variables that are thought to directly influence the amount of persistence students invest in learning tasks. Ford (1992) describes a multiplicative relationship between control values, mood and agency (domain self efficacy and expectancy beliefs about the application context for what is learned). Clark (In press, 1999) has described these three variables as a series of questions students ask themselves constantly as they learn: “Will the knowledge I gain help me become more effective?” (control value); “Do I feel like learning this information?” (mood); and “Can I do it? And if I can, “Will I be encouraged/permitted to use what I learn later?” (agency). Since the relationship between all three variables is multiplicative (value x mood x agency), if the value of any one variable slips below a tolerance threshold, persistence and learning stop. Unlike the defaults at both low and high levels of self efficacy, there is no comparable default at very high levels of value, mood or agency.

A balanced, cognitive “Yin and Yang” process model is suggested to help understand the types of mental processes that lead to default behavior. It is suggested that as learning tasks become more novel and declarative, cognitive load increases and students must find different and novel learning strategies to achieve learning goals. These “Yin” (different, novel) processes lead to both efficacy and control defaults where automated behaviors tend to force students into different and/or novel and destructive goals and mistakes. When learning goals emphasize the acquisition or use of automated procedural knowledge, “Yang” (similarity, familiar) processes search working declarative and procedural memory for familiar learning strategies and goals. Yang processes can lead to over confident defaults. Essentially, Yin processes result from more novel goals and at extreme levels, introduce novel mistakes. Yang processes result from the use of familiar, often automated knowledge, and introduce familiarity (overconfident) mistakes and a rejection of responsibility.

Since learner self efficacy, value, mood and agency can be monitored through self report questions, it is suggested that MMI designers monitor subtle changes in these variables, and changes in the indicators of mental effort (increasing numbers of mistakes on practice exercises) and persistence (delay, poor scheduling of work, dropping out). As we develop more subtle and effective ways to handle motivational issues in complex learning environments, we may find methods for collecting efficacy, value, mood and agency profiles of each learner in order to intervene before default precursor reach potentially harmful levels. Large individual and cultural differences exist to influence student efficacy and control beliefs. We need to collect

learner-specific information about instructionally-controllable events perceived as reducing or increasing task and domain self efficacy, control values, mood and context beliefs (agency). Until the time when such information is available, MMI designers and developers are advised to:

- 1) Avoid the urge to use the full display capacity of MMI systems to format, colour, animate, exemplify, link and provide endless alternatives to learners. Emphasize only the critical instructional information necessary to compile, encode, elaborate and practice knowledge;
- 2) be alert to the possibility that any instructional format or method that helps one student may be perceived as threatening or discouraging to another student;
- 3) Focus feedback on the gap between specific learning goals and immediate learning, not on the learner's "wrong behavior" or intentions;
- 4) Attempt to maintain each learner at low to moderate levels of immediate task self efficacy by always providing instruction at a cognitive load that reflects the maximum challenge possible without risking efficacy, overconfident or control defaults and yet encourage positive domain self efficacy to maintain persistence; and
- 5) avoid the temptation to provide learning strategy instruction for more experienced or higher ability students if that instruction might interfere with previously automated learning strategies.

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