TRAINING TEAMS TO TAKE INITIATIVE: CRITICAL THINKING IN NOVEL SITUATIONS

by

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11 September 1999

TEAMWORK AND INITIATIVE

A U.S. Army infantry handbook published in 1939 states, “The art of war has no traffic with rules, for the infinitely varying circumstances and conditions of combat never produce exactly the same situation twice.” Much the same can be said about business environments characterized by rapidly shifting technologies, markets, and competitive landscapes. The purpose of this chapter is to explore how members of military, business, and other organizations cope with uncertainty, change, and conflicting purposes. It will focus on (1) the cognitive skills that individuals need to function effectively in such organizations, and (2) on methods for training those skills.

We will focus on skills that enable individuals or subteams to take the initiative within a team context. We can start by distinguishing two advantages that teamwork provides over an individual acting alone: (1) The first advantage is based on *bringing together complementary inputs,* and derives from the coordination of multiple hands, eyes, heads, etc. to accomplish a complex task. Increased effectiveness comes from sharing of both physical and cognitive workload and through specialization of knowledge and skills. (2) The second advantage is based on *choosing from among substitutable alternatives*, and derives from the diversity of competing solutions to the same problem that different members of a team can generate. Better decisions result if there is an effective organizational mechanism for selecting from, averaging, or mixing these diverse ideas to arrive at a single decision (e.g., Kerr, MacCoun, & Kramer, 1996).

Teamwork is not guaranteed to provide either of these advantages. With respect to (1) combining complementary inputs, increasing the size of an organization tends to reduce its overall efficiency unless there is also an increase in departmentalization and standardization of tasks (Blau, 1970). The latter features, however, reduce flexibility of response in a changing or novel environment (Donaldson, 1995). A related problem is *goal displacement*, in which specialized units lose sight of the larger organizational purpose, and pursue their own goals as if they were fixed ends rather than means, which should be reevaluated when conditions change (Scott, 1998). With respect to (2) better decisions, groups may be affected by socialization biases, such as “groupthink,” which induce conformity rather than diversity of thought (Janus, 1972; March, 1996.). For this reason, group decisions tend to be better when individuals think about the problem independently before arriving at a group judgment (Castellan, 1993; Sniezek & Henry, 1990). Both challenges –speed of response to change and innovative thinking – can be addressed by organizational structures that emphasize *decentralization*: granting individuals or subteams the autonomy to make decisions in their own spheres (Burns & Stalker, 1961; Van Creveld, 1985). In some cases, outcomes may be better when individual team members bypass standard procedures, question the accepted beliefs or practices of the group, and act on their own responsibility.

The degree of appropriate autonomy varies. Decentralization and initiative are adaptive responses to specific organizational environments, and are not everywhere appropriate. Interdependency among team tasks heightens the importance of coordination (Thompson, 1967), whether it is achieved implicitly on the basis of shared knowledge of tasks, procedures, and other team members (Cannon-Bowers, Salas, and Converse, 1993; Cannon-Bowers, Tannenbaum, Salas, & Volpe, 1995; Kleinman & Serfaty, 1989), by contingency planning that begins when unexpected possibilities first become apparent

(Orasanu, 1993), or by mutual monitoring, feedback, back-up, and closed-loop communication as the tasks are carried out (McIntyre & Salas, 1995). On the other hand, when the task environment is rapidly changing and uncertain, and individuals or teams are *spatially dispersed*, decentralization and initiative gain in importance. This is a not uncommon predicament in combat: Company E's job is to guard Company F's flank while Company F secures a bridge that the division intends to cross. Now, however, Company F appears to be stalled in a major firefight some distance from the bridge. Company E cannot raise either Company F or higher headquarters on the radio (and it will take too long for runners to find them and return). Should Company E sit tight until Company F is ready to seize the bridge or until communications are reestablished? Should it go help Company F in the firefight, at the risk of getting bogged down itself? Or should Company E attempt to seize the bridge now – a risky choice, but possibly the only way to accomplish the higher-level purpose of supporting the division in a timely manner?

The combination of time stress, spatial separation, and uncertainty – along with varying degrees of task interdependency – can alter the nature of teamwork, overlaying a set of qualitatively different decision tasks on the traditional ones. For example:

- *Should we communicate?* When events unfold in an unanticipated manner (*uncertainty*), advance planning and shared task understanding may fail to bring about coordination. Yet the *dynamic* character of the situation limits real-time communication. *Spatial separation* imposes a bandwidth limitation on communication, exacerbating the impact of both uncertainty and time constraints. The upshot is that real-time closed-loop communication can no longer be regarded as routine. When an unexpected, time-critical problem arises, team members or subteams must decide whether or not the potential benefits of communicating and/or waiting for a response are worth the delay.
- *What will other team members do?* In time-critical situations, subteams will sometimes be unable to communicate, or choose not to communicate, with one another. If their tasks are interdependent, however, the success of one will depend on coordination with the actions of another. In these cases, team members or subteams must make autonomous decisions that depend on plausible assumptions about concurrent decisions being made by other subteams in other locations. Shared task, team, and team member models may help support such predictions, but cannot be fully relied on in novel circumstances.
- *How good is the information?* Even when team members and subteams do decide to communicate, the combination of bandwidth and time constraints will prevent them from sharing information fully. Communications (e.g., reports, feedback, orders, or advice) from another subteam will have to be evaluated with incomplete understanding of the sources and assumptions behind them, and, conversely, with the benefit of other information that is available locally but not to the subteam that originated the message.

In the next section, we will briefly describe an empirically based theory that addresses skills of this kind. We will argue that the skills underlying initiative involve *critical thinking about mental models* of the task and the team. We illustrate the application of the theory by means of an actual example of initiative within a team, in a context where the degree of decentralization of authority happened to be somewhat ambiguous. We then describe a training strategy that is based on the theory and which focuses on the mental models and critical thinking skills that underlie decisions about initiative. The value of such training should be quite general. Virtually every team is to some degree a *distributed* team. Even when team members are within plain sight and hearing of each other (e.g., in an emergency room, airline cockpit, or the combat information center of a cruiser), the high workload associated with uncertainty and time stress can be quite sufficient to limit the rate of communication (Kleinman & Serfaty, 1989) and make initiative essential.

AN EMPIRICAL AND THEORETICAL FRAMEWORK

Studies of expert-novice differences suggest that expertise develops along two paths over time, one leading to better performance in *familiar* situations, the other leading to improved ability to handle *unusual* situations. A considerable body of research has focused on the first path: Experts accumulate a large repertoire of patterns and associated responses, which they use to recognize and deal quickly with familiar situations (Chase & Simon, 1973; Larkin, McDermott, Simon, & Simon, 1980; Klein, 1993). The difference between experts and novices, however, goes well beyond the quantity of patterns they draw on or the number of situations they regard as familiar. In fact, a key hallmark of expertise is *goal-setting*, or intentional creation of novelty. In fields such as writing and historical or scientific research, for example, experts are more likely than novices to identify opportunities for original, productive work, establish their own goals, and create challenging tasks for themselves, which cannot be solved by pattern matching alone (Ericsson & Smith, 1991; Anzai, 1991; Holyoak, 1991). Novel ideas and strategies are also important in military and business environments.

When performing a challenging task, whether self-created or externally imposed, experts and novices differ in other ways that are not fully accounted for by pattern recognition. Scardamalia and Bereiter (1991) found that expert writers, compared to novice writers, discovered more problems with their own work and struggled longer to find solutions, revising both their goals and their methods more often than novices. Patel and Groen (1991) found that expert physicians spent more time *verifying* their diagnoses than did less experienced physicians. Physics experts are more likely than novices to check the correctness of their method and result, and to actively change their representation of the problem until the solution becomes clear (Larkin, et al., 1980; Larkin, 1981; Chi, Glaser, and Rees, 1982). Expert programmers pay more attention to the goal structure of a task than novices, searching first for a global program design, while novices tend to be more “recognitional,” plunging rapidly into a single solution (Adelson, 1984). In foreign policy problems, expert diplomats spent more time formulating their goals and representing the problem, while students primarily focused on the options (Voss, Wolf, Lawrence, & Engle, 1991). VanLehn (1998) found that less successful physics learners were more likely to solve new problems by analogy with old problems (a recognitional strategy), while more successful learners used general methods for solving new problems, drawing on analogies only when they reached an *impasse* or wished to *verify* a step in their solution. Chi, Bassok, Lewis, Reimann, & Glaser (1987) found that better performing physics students were more likely to generate self-explanations and self-monitoring statements than poor students. Glaser (1996) identifies effective self-evaluation and self-regulation as key components in the acquisition of expertise.

Tactical battlefield problems tend to be viewed differently by experts and by novices. Novices often regard them as puzzles, which have "school book" solutions, while more experienced officers view them in a more challenging light, acknowledging the possibility that the enemy may not succumb so readily to a predictable course of action. Serfaty (1993) compared experienced Army planners to novice planners, and found that the experienced planners did not appear to use recognitional strategies; that is, they did not perceive more similarities with prior situations, did not generate plans more rapidly, tended to see the situation as more *complex*, were less *confident* in their solutions, and felt the need for more *time* than novices. Among the distinguishing features of experts that Shanteau (1992) identified in his research was the ability to handle adversity, to identify exceptions, and to adapt to changing conditions (Shanteau, 1992).

If expertise develops along two paths, what is the nature of the second, non-recognitional path? One view distinguishes it sharply from the first path: Experts define and deal with challenging problems by substituting formal analytical methods for pattern matching. This is the general approach urged by decision analysts (e.g., Watson & Buede, 1987), who define *normative* methods that require breaking novel problems down into component parts (e.g., options, outcomes, goals), assessing them quantitatively, then recombining them in order to calculate a recommended decision. The research reviewed above, however, suggests that this characterization of the second path is wrong. Formal methods are both too time-consuming, and too divorced from the knowledge experts have accumulated (Cohen, 1993). Dreyfus (1997) puts it well: "Usually when experts have to make such decisions they are in a situation in which they have already had a great deal of experience. The expert, however, is not able to react intuitively, either because the situation is in some way unusual or because of the great risk and responsibility involved… the experts draw on their context-based intuitive understanding, but check and refine it to deal with the problematic situation… Deliberative rationality is detached, reasoned observation of one's intuitive practice-based behavior with an eye to *challenging and perhaps improving intuition without replacing it*..." [italics added].

Instead of dropping pattern recognition in novel situations, experienced decision makers learn to pause and *think critically about the results of recognition*. They ask, in effect: "What in this situation conflicts with my expectations? How can I stretch the pattern, i.e., tell a new story, to make the pattern fit? What assumptions must I accept to believe this story? What information is missing that would clarify the assumptions? How plausible is the story? What alternative patterns might apply? What story must I tell to make one of these other patterns fit, and what assumptions does it require? Which story is more plausible?" Reflective processes of this kind amplify the power and flexibility of recognitional processes without altogether throwing away their advantage in rapid access to knowledge. Moreover, critical thinking can make itself unnecessary the next time round. Decision makers sometimes handle novel situations by identifying regularities underlying exceptions to known patterns. Mental models embodying these newly discovered regularities provide patterns that can be recognized in later situations (Chi et al., 1981; McKeithen et al., 1981; Adelson, 1984; Larkin et al., 1980; Thompson, Cohen, & Shastri, 1997).

Because their function is to monitor and regulate recognition, we call the reflective processes used in unusual situations *metarecognitional*.[1] and we call this framework the Recognition / Metacognition Model (Cohen, Freeman, & Wolf, 1996; Cohen, Freeman, & Thompson, 1998). The R / M model implies that the two paths along which expertise develops are intertwined. Reflection increases the power of recognition, but itself gains power as a base of recognitional knowledge is built.

It is reasonable to suppose that expertise in *teamwork* evolves with increasing experience in a domain along the same two paths as expertise in *taskwork* (McIntyre & Salas, 1995). Yet Orasanu & Salas (1993) note that "most current team training aims at developing habits for routine situations… Habit and implicit coordination will carry people a long way in routine situations; we need to prepare them for the unusual." In this chapter we will explore how the dual nature of expertise sheds light on the tension between initiative and coordination in teamwork, and provides a framework within which both initiative and coordination can be trained.

Mental Models Underlying Initiative

Initiative means taking "the first step, or the lead; the act of setting a process or chain of events in motion" (Brown, 1993). Extending this definition, we can define *degree of initiative* in terms of *when* in a chain of events someone intervenes and the amount of influence over the chain of events that person achieves: the earlier and more influential the intervention, the more initiative the person has shown with respect to that process. Interventions are often (though not always) targeted at the decision-action-outcome cycle of other agents. In business, for example, one may try to influence, predict, or react to the actions of competitors, customers, superiors, subordinates, or co-workers. In combat, one may try to influence, predict, or react to actions of the enemy, other friendly forces, superiors, or subordinates. In all these cases, greater initiative means that the decision-action-outcome cycle of other agents has been more thoroughly shaped in accordance with your own goals or purposes. The essential questions for training are: What must people know, and how must they think about what they know, to make appropriate decisions about initiative within an organization? What are the mental models and the critical thinking processes that underlie initiative?

The following analysis is based on 25 critical incident interviews and problem-solving sessions with active duty Army officers serving on operations, planning, and intelligence staffs at a variety of organizational levels (battalion, brigade, division, and corps). The goal of our analysis was to uncover cognitive structure beneath the surface descriptions of the incidents.

Structure was extracted in three successive stages: (1) We grouped judgments and decisions within the incident that occurred at the same time or in reference to the same event. We then classified these judgments and decisions by topic, using categories relevant to the domain, such as the higher level *purpose* of an operation, enemy or friendly *capabilities*, observation or analysis of *terrain*, enemy or friendly *intent*, enemy or friendly *action*, enemy or friendly *rate of movement*, *reliability* of an information

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[1] This name is by analogy to other so-called *metacognitive* skills, such as *meta-memory* (skills for monitoring and improving memory performance), *meta-attention* (skills for improving the control of attention), and *meta-comprehension* (skills for monitoring and improving the understanding of text). See Forrest-Pressley, MacKinnon, & Waller (1985); Metcalfe & Shimamura (1994); Nelson (1992).

source, and so on. (2) We then identified clusters of such topics that tended to be correlated with one another within and across incidents, e.g., assessments of enemy intent were found to be based on assessments of enemy capabilities, terrain, enemy doctrine, and enemy actions. These correlated groups of concepts typically constitute a narrative, or *story*, about how certain kinds of events are expected to lead to other kinds of events (Pennington & Hastie, 1993). We call these correlated groups of concepts, together with their implicit or explicit causal relationships, *mental models*.

In addition to mental models, three degrees of initiative, or *time orientations*, were defined as shown in Figure 1, in terms of where and how they intervened in the chain of events representing another agent's decisions, actions, and outcomes. The *proactive* time orientation represents the maximum amount of initiative. It was present if a friendly action was designed to *influence* future enemy or friendly intent (e.g., to eliminate an enemy option or lure the enemy into a trap; to degrade the enemy's decision making process; to create an opportunity for a specific action by another friendly unit; or to influence a decision by your own commander). The *predictive* time orientation represents the next highest degree of initiative. It was present if a friendly action was adopted because a future enemy or friendly action was expected to occur (without our doing anything special to bring it about). Predictive actions include disrupting or defeating the planned enemy action; exploiting an enemy weakness or avoiding an enemy strength that will be caused by the enemy action; and preparing to provide support where and when other friendly forces are likely to need it. The *reactive* time orientation represents the least amount of initiative. It occurred when a friendly action was adopted because of an enemy or friendly action already accomplished or underway (e.g. to limit the damage from a surprise attack; to take advantage of an enemy blunder; or to rescue a friendly unit in trouble).[2] The three time orientations are not mutually exclusive. A decision maker might be reactive at one level but proactive and/or predictive at other levels, with respect to other decision cycles that belong to the same or different agents.

Insert Figure 1 about here

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(3) The third stage of analysis involved examining correlations of mental models and time orientations with one another and with other variables. We can visualize this level of structure by placing the mental models, time orientations, and other variables in a multidimensional space, as shown in Figure 2. The closer any two items are situated in this space, the more highly correlated they were across incidents (Kruskal, 1964). In addition to mental models and time orientations, two variables are also shown: officers' experience and the degree to which an incident surprised them.[3]

[2] The same concept of initiative could also be applied to intervention in natural chains of events, e.g., proactively preventing a hurricane by seeding a tropical storm, predicting and preparing for the hurricane's point of impact, or reacting by declaring a state of emergency after it hits.

[3] To score the presence of a mental model in the description of a particular incident, we required the explicit mention of only two or more out of the cluster of correlated topics defined as components of that kind of model (see step 2). For example, an *intent* model was scored as present if the description mentioned (i) enemy or friendly intent and (ii) two or more reasons to adopt that intent (e.g., an opportunity or

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Insert Figure 2 about here

Initiative is a good organizing principle for the mental models in this space. Analysis of the correlations in Figure 2 (Johnson, 1967) reveals three basic clusters of mental models, corresponding to the three time orientations: *reactive*, *predictive*, and *proactive*. The two dimensions shown in Figure 2 are suggestive. They are anchored on the three clusters, and provide a natural interpretation of the contribution of different mental models to initiative. One dimension reflects *when* uncertainty about another agent's action is reduced (early versus late), and the other reflects *how* it is reduced (by assessment or by action).

Mental models of the *other agent's intent* and of *one's own intent* were utilized approximately equally often by decision makers who were trying to predict intent as by decisions makers who were trying to influence it. However, proactive decision makers, who attempt to make others act in accordance with their own intent, were most likely to think deeply about their own intent, i.e., to use mental models of higher-level *purpose*. On the other hand, predictive decision makers were more likely to use the *rate of movement* mental model. Mental models of *reliability* were used both in the predictive orientation (to evaluate predictions ahead of time) and in the reactive orientation (to figure out why a prediction failed). Similarly, *alternative causes and effects* were considered most often in reactive modes, when decision makers tried to explain a failed expectation. Mental models of *action sequence*, which specify how one's own actions are to be carried out, were approximately equally important in all three time orientations.

In sum, concepts in this domain appear to be organized into a set of mental models, including *purpose*, *intent*, *action sequence*, *alternative causes and effects*, and *reliability*. These models in turn are organized around a set of more fundamental principles pertaining to the time and manner in which uncertainty about other agents is reduced (the axes and clusters depicted in Figure 2). Since reactive, predictive, and proactive time orientations represent increasingly influential interventions in another agent's decision cycle, moving horizontally from left to right in Figure 2 (which affects both how and when intervention takes place) represents increasing *initiative*. Initiative in this sense is highly correlated with experience. There was a significant correlation between experience level and being proactive, and also a significant correlation between experience level and considering higher-level purposes. As Figure 2 indicates, when decision makers advance from low to high experience, they tend to move from the cluster of mental models associated with reacting to unexpected events, to the cluster containing both predictive

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capability) or indicators of that intent (e.g., resulting actions or outcomes). *Purpose* was scored as present if the description mentioned (i) friendly intent that is motivated by (ii) a higher-level goal or a longer-term objective extending beyond own unit's mission, or a general principle of warfighting. *Action sequence* involved (i) two or more enemy actions or two or more friendly actions (ii) with the explicit constraint that one must be performed before the other. *Reliability* involved (i) a claim regarding the situation, a predicted enemy or friendly action, or the best friendly course of action, (ii) explicit mention of the source of the claim or recommendation, and (iii) an assessment of its reliability.

and proactive strategies. It remains now to consider how these mental models are used in decision making.

Critical Thinking about Mental Models

The basis for decision making, more often than not, is recognition, and in ordinary circumstances, the recognitional responses of experienced decision makers are likely to be adequate (Klein, 1993). In such situations, perceptual inputs and goals rapidly converge within a decision maker's mind onto one, and only one, stable "intuitive" decision. In more unusual situations, however, recognition needs to be supplemented by other processes.

Recognitional learning enables humans (and other animals) to acquire adaptive responses to environmental conditions that arise with some regularity during a single lifetime, even when they have not appeared in the previous history of the species. At this scale, the effect of natural selection on inherited stimulus-response connections would be far too slow. On the other hand, recognitional skill may itself take many years to reach the expert level in a particular domain; how long it takes will depend on the extent of the environmental variability that must be mastered. *Critical thinking* provides a further gain in flexibility in rapidly changing or novel environments, where recognitional learning is itself too slow. Critical thinking enables decision makers to find adaptive responses to even finer-grained environmental variations, which may not have appeared at all in the previous experience of the decision maker. It does so by building a relatively simple layer of control over the recognitional processing that is already taking place. The simplicity of the required control processes (described below), along with their potential importance, lends plausibility to the hypothesis that such a second-order capability could have evolved, and that specific skills drawing on that capability could be shaped by individual experience.[4]

Critical thinking includes *meta-recognitional* processes that monitor and regulate recognition. As shown in Figure 3, the Recognition / Metacognition model distinguishes three basic metacognitive functions: (1) The *Quick Test*, which is a rapid assessment of the value of taking more time for critical thinking versus acting immediately on the current recognitional response; (2) *critiquing* the current results of recognition in order to identify problems; and (3) *correcting* those problems by influencing the operation of the recognition system. Previous descriptions of the R/M model may be found in Cohen, Freeman, & Wolf (1996) and Cohen, Freeman, & Thompson (1998; see also Cohen, Parasuraman, Serfaty, & Andes, 1997).

Insert Figure 3 about here

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[4] The hypothesis that meta-recognitional strategies can be learned through experience is being tested by experiments with a computational implementation of the Recognition / Metacognition model. The implementation utilizes a connectionist architecture with a backpropagation learning algorithm, and employs temporal synchrony of firings for consistency of object reference in relational reasoning (Thompson, Cohen, & Shastri, 1997).

A fundamental meta-recognitional skill is distinguishing *grounds*, i.e., what is given in a particular situation, from *conclusions*, i.e., what is inferred or decided in that situation (Kuhn, Amsel, & O'Loughlin, 1988). This must be a real-time discrimination, because the same event may serve as evidence in one situation and as a recognitional conclusion in another. For example, in one situation the observation that a missile site is active may rapidly lead to the recognitional conclusion that the enemy intends to fire a missile and also to the decision to strike the missile site. In another situation, intelligence that the enemy intends to fire at a U.S. ship might rapidly lead to a prediction that the missile site will go active.

The relationship between grounds and conclusion on a particular occasion is an *argument* (Toulmin, 1958), which may or may not be compelling. Meta-recognitional processes focus on the credibility of *recognitional* arguments (other types of arguments are based on principles other than recognition, e.g., logic, theory, or expert authority). In critiquing, the decision maker looks for *uncertainty* in the arguments composing the present recognitional conclusion. There are three ways that recognition can fall short, i.e., ways in which it can fail to produce one and only one stable conclusion. These three kinds of uncertainty correspond to situations in which (i) *more than one* conclusion seems plausible, because of *gaps* in knowledge or values, (ii) *less than one* (that is, *no*) conclusion seems entirely plausible due to *conflicting* beliefs or values, or (iii) the conclusion is subject to *variation* over time, because of shifting, *unreliable* assumptions about beliefs or values.

Critical thinking addresses these problems by removing one major limitation on recognitional learning: that the situation and the response retrieved to handle it must have been closely associated in the individual's previous experience. The mechanisms that overcome this limitation involve relatively simple processes of controlled attention. One important meta-recognitional correcting step involves shifting attention from cues in the situation (perceptual grounds) to selected elements of the current recognitional conclusion. The result is activation of potentially relevant knowledge in long-term memory that has not yet played a role in the present argument because it is too distantly related to the situational cues. Activation of this new information may lead, via recognitional processes, to activation of still more indirectly related knowledge, to which attention may then be shifted, and so on. The newly activated information may then serve as the grounds for new arguments regarding the conclusion. Such attention shifting is equivalent to *posing queries* about the acceptability of the currently active situation model and plan (Shastri & Ajjanagadde, 1993; Thompson, Cohen & Shastri, 1997).

A more directive variant of attention shifting is to *persistently* attend to a *hypothetical* or *counterfactual* action or event. Persistent attention to such a possibility is equivalent to assuming or imagining that it is true, and posing a query about what *would* happen if the hypothesized action or event were the case (Ellis, 1995). This strategy extends the reach of recognitional processing even further, by activating relevant knowledge that is not directly associated either with cues in the actual situation or with the recognitional conclusion. This newly activated information may also serve as grounds for new arguments, e.g., for or against alternatives to the current situation model and plan.

The result of attention shifting strategies of either kind is always to increase (or at least never to decrease) the amount of knowledge brought to bear on a problem. Attention shifting, however, operates in different ways and has different consequences in response to different types of uncertainty. It is likely that experienced decision makers learn meta-recognitional strategies that reflect these differences:

- To identify and fill *gaps* in an argument (the case where more than one conclusion is consistent with the current evidence), attention shifts to one of the possible conclusions – in effect, querying its truth. The result is activation of an associated *mental model*, which indicates the types of information that have been useful in the past in determining the truth or falsity of the attended conclusion. (For example, in order to determine the *intent* of an enemy unit, it is useful to consider the *capabilities* of that unit, as well as its *opportunities*, *goals*, and *actions*.) Attention then shifts to one of the components of the activated mental model for which information is not currently active (e.g., the decision maker decides to think about the *capabilities* of the enemy unit whose intent is uncertain). The result may be retrieval of relevant information in long-term memory about that component, or, if relevant information is not retrieved, a decision to initiate external data collection.

  A more directive strategy for activating relevant knowledge in long-term memory is to temporarily assume that a conclusion is correct, by persistent attention to that possibility. This and subsequent shifts of attention may activate less immediately accessible information about the likely long-term consequences of an option, or about the less obvious implications of a hypothesis.

  Knowledge activated by these attentional strategies may help narrow down the set of plausible conclusions (i) by showing that one or more of the conclusions *conflicts* with existing goals or beliefs, or (ii) by uncovering the relevance of new goals or beliefs that further *constrain* the solution. There are three possible outcomes of these correcting steps. First, if newly activated knowledge eliminates all but one plausible conclusion, the problem is solved, i.e., there is now one and only one stable conclusion. Second, the result may be a new problem, *conflict*, if *no* conclusion appears to satisfy all the newly discovered constraints. Third, the result may be another kind of problem, *unreliability*, if the elimination of options is the result of as yet unconsidered assumptions rather than firm knowledge.

- One method for identifying *conflict* is to fill gaps as just described. Newly retrieved or collected information may expose hitherto hidden conflict between a conclusion and existing goals or beliefs. Another, more directive strategy for identifying conflict is to temporarily assume (by persistent attention) that a conclusion is *wrong*, in effect tasking the recognition system to activate an account of how that could happen. This tactic heightens the salience of negative information about the conclusion, e.g., possible bad outcomes of an option or reasons why a hypothesis might not be the case. Awareness of this information may have previously been suppressed by stronger positive information.

  Conflict among arguments (the situation in which there are grounds for both accepting and rejecting every conclusion) can be addressed by shifting attention to the sources of information or to the goals that are responsible for the conflict. As a result of this shift in attention (and subsequent shifts to which it leads), it may be learned, for example, that (i) one or more conflicting sources of information are not as credible as previously supposed, (ii) one or more sources of information were misinterpreted in some way, (iii) one or more conflicting goals are not as important as previously supposed, or (iv) one or more options does not in fact conflict with a goal as previously thought. In this case, additional knowledge *removes* constraints on the recognitional conclusion, rather than adding constraints as in the case of filling gaps. Attention shifting reveals that what was previously thought to be a constraint on belief or action (e.g., a report from an information source, or a goal) was based on assumptions (Doyle, 1979; Cohen, 1986).

In the more directive version of this correcting step, the decision maker temporarily assumes (by persistent attention) that one of the conflicting conclusions is *correct* despite the information or goals that conflict with it, thus tasking the recognition system to activate an account of how this could be. Alternatively, the decision maker assumes that a specific source is not credible, or a specific goal is not important, etc., tasking the recognition system to account for how this could be. Such directive techniques can increase the chance that hitherto inactive knowledge in long-term memory about the relevant sources or goals will be retrieved.

There are three possible results of these correcting steps. First, the problem is solved if newly activated knowledge convincingly undermines the original reason for rejecting one and only one of the competing conclusions. For example, newly activated knowledge may establish that one of the conflicting information sources is not credible or that one of the conflicting goals is not important. Second, these correcting steps might resurrect more than one conclusion, by undermining the reasons for rejecting them, thus leading back to the problem of gaps in arguments. Third, these correcting steps may lead to *unreliability*, if the activation process does not actually refute the initial assumptions but simply reverses those assumptions. Acceptance of one and only one conclusion will then depend on the *possibility of imagining* that a particular information source is not credible or that a particular goal is not important. Conclusions based on possibility in this way are, of course, subject to change. A decision maker may or may not be explicitly aware of such assumptions.

- To address *unreliability*, a decision maker must first *identify* key assumptions underlying possible conclusions and then *evaluate* them. Identification of hidden assumptions is not trivial. A decision maker may have a high degree of confidence in the initial recognitional response to a situation, and yet that conclusion may turn out to depend on questionable assumptions, for example, that the present situation resembles previously experienced ones in important respects. In addition, as we have seen, when the initial recognitional response is uncertain, correcting steps to fill gaps or resolve conflict can smuggle in assumptions that are not even noticed by the decision maker. Instability of conclusions over time, or variability in the conclusions of different decision makers at the same time, are symptoms that unreliable assumptions could be playing a role. However, (a) variability per se does not indicate *what* the problematic assumptions are, and (b) variability is not always available as an indicator.

In a group context, a strategy for identifying assumptions is for decision makers to articulate *reasons* for their divergent conclusions and then to compare these justifications. Openness to such a dialogue is, of course, a natural part of a healthy group decision making process (e.g., Helmreich & Foushee, 1993). When variability does not exist, because there is a single convincing conclusion, disagreement can be induced more artificially, by assigning some individuals the task of "red-teaming" the preferred conclusion or playing the role of devil's advocate. Each potential problem discovered in this way represents an assumption implicit in the favored solution, to the effect that the relevant problem will not materialize.

Skilled decision makers use attention-shifting strategies to simulate these group processes. No matter how confident they are in a particular conclusion, one powerful approach is to assume that it is *incorrect* (through persistent attention to that possibility), in effect querying the recognition system for an explanation of how that could be. If they are persistent enough, an explanation for the falsity of the prediction or the failure of the plan will be generated. Decision makers may then imagine that this is not the correct explanation for the failure, and force the recognition system to activate another explanation, and so on. Each explanatory possibility activated in this way corresponds to an assumption. If the decision maker expects the preferred conclusion to succeed, the decision maker must be comfortable assuming that each possibility of failure that can be generated is false.

The mere fact that a conclusion depends on untested assumptions is not sufficient cause to reject it. First, we never know with certainty that we have successfully identified all the assumptions underlying any given conclusion (a constructivist view of knowledge would suggest that it is impossible in principle). Second, because of limitations on time, only a small number of assumptions can be evaluated in any depth, e.g., by shifting attention to activate knowledge that bears on their plausibility. Third, in the novel situations where critical thinking is appropriate, some crucial information will inevitably be unavailable (gaps), and no conclusion will fit all the observations or goals perfectly (conflict). If gaps and conflicts are to be resolved at all in these cases, it will have to be by means of assumptions.

In fact, real-world decision makers often use an *assumption-based correcting strategy*. They attempt to fill gaps and resolve conflicts in a recognitional conclusion, by retrieving or collecting information if possible but by making assumptions where necessary. They continue this process until they have a *complete* and *coherent* story. In effect, they ask themselves, "What is the best story I can tell to justify this inference or plan?" They then step back, take a look at the story they have created, and try to evaluate its plausibility *as a whole*. In particular, they ask, "What assumptions did I have to make to build this story? Are the assumptions I had to make credible in this situation?" If the assumptions are troubling, the decision maker may temporarily drop them, re-establishing the gaps and conflict that the assumptions were intended to handle. The decision maker may then fill the gaps and resolve the conflicts with a new story, supporting a different conclusion. The choice between competing hypotheses or actions is often made based on evaluation of the plausibility of the assumptions underlying competing stories (Pennington & Hastie, 1993).

As the preceding discussion makes clear, meta-recognitional processing is a highly iterative, open-ended, and flexible process. The solution to one type of problem (e.g., filling a gap) can lead to another type of problem (e. g., conflict), which prompts new correcting steps, leading to new problems (e.g., unreliable assumptions), and so on. In the course of this process, recognitional conclusions are improved and/or modified bit by bit through local decisions about what to do next, and an understanding of the strengths and weaknesses of alternative conclusions is developed at the same time. These improvements are accomplished across cycles of shifting attention that either activate long-term memory contents that lay beyond the reach of a single recognitional cycle or lead to external information collection. When further benefits are likely to be outweighed by the costs of additional delay, critical thinking stops, and the decision maker can act immediately on the current best solution to the problem.

In most of these respects, meta-recognitional processing contrasts with formal analytical approaches to decision making. Typically, formal methods require a problem structuring stage which specifies in advance the inputs and analytical steps that will be used to model the problem. These inputs and analytical steps are not related in any direct way to recognitional responding and the knowledge that it taps. Although some iteration of modeling may take place, along with sensitivity analysis of the results (e.g., Watson & Buede, 1987), "thinking" is largely over and a solution is available as soon as, but not a moment before, the model is finished according to the prespecified blueprint.

EXAMPLE: "ASK FORGIVENESS, NOT PERMISSION"

As we saw earlier, initiative is a matter of *time*: acting early enough to influence another agent in accordance with one's own purposes. Yet, as we have just seen, critical thinking takes more time than simple recognition. It is reasonable to ask, then, whether or not critical thinking is consistent with the tempo of decision making demanded by initiative. We argue that it is. Rapid recognitional responding can, in some situations, trap a military decision maker in a reactive mode with respect to the enemy, or trap a business decision maker in a reactive mode with respect to competitors and customers. Seizing the initiative will often be impossible in the absence of critical thinking about innovative solutions that bypass standard procedures. The following incident (based on an interview conducted as part of the Navy's Tactical Decision Making Under Stress (TADMUS) program; see Kaempf, Klein, Thordsen, & Wolf, 1996) is an excellent illustration of how critical thinking about mental models can support initiative, and how the time cost of critical thinking can simply be dwarfed in comparison to the advantages of the proactive tactics to which it leads.[5]

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[5] Our work on Navy decision making was supported by Contract No. N61339-96-C-0107 with the Naval Air Warfare Center Training Systems Division, as part of the TADMUS program.

Initial recognitional response

A U.S. naval officer was serving as the Anti-Air Warfare Coordinator (AAWC) on an Aegis cruiser in the Persian Gulf, when he received intelligence reports that an Iraqi Silkworm missile site had suddenly gone active. The site was a threat to a large number of U.S. surface ships assembled in the area at the start of the air war against Iraq. Unfortunately, no airborne strike aircraft were close enough to be used against the missile site. The first thing that occurred to the AAWC, i.e., his *recognitional response*, was the standard procedure for this situation: Ask the Tactical Operations Officer (TAO) on his own cruiser to call the Battle Force TAO and request that strike aircraft be launched from the carrier to destroy the newly activated missile site.

Quick Test: The AAWC was initially in a *reactive time orientation* with respect to the Iraqi missile site's turning on its fire control radar. Whatever he chose to do was designed to mitigate any advantage the enemy might derive from that surprise move. His *purpose*, however, quickly became *proactive* with respect to the enemy's launching a missile, an option that he wished to eliminate. The question, then, was: Will the standard procedure be effective and timely in destroying the missile site as quickly as possible? Rather than immediately carrying out the standard procedure, the officer paused momentarily to critically evaluate it.

Critiquing the initial recognitional response

Find conflict: One problem with the recognitional response came to mind immediately, based on a mental model of *team member reliability*. The officer recalled a previous experience when carrier staff failed to take into account updated information about target coordinates. *Resolve conflict by adopting an assumption:* Rather than immediately give up the initial recognitional response, the AAWC tried to repair it as well as he could. The standard procedure would be justified if the AAWC could assume that this situation was in crucial ways different from the previous one. *Evaluate assumption:* In fact, there was a difference: He was able to provide the required targeting information earlier now than he had on the previous occasion. Despite this difference, the AAWC believed that the magnitude of the previous error indicated a strong possibility that the deck-launched intercept would not be properly targeted. He was not comfortable with the assumption.

Fill gaps by retrieving information: The AAWC was also concerned about the speed with which a missile strike could be implemented, so he decided to scrutinize the recognitional response further. He imagined that the standard procedure was adopted, stepped through the expected *action sequence* in his imagination, and looked for problems (Klein, 1993). In doing this, he drew on mental models of *action sequence*, *rate of movement*, and *team member reliability*. He predicted that the Battle Force AAWC would pass the request to the Battle Force TAO, who would probably bring in the Commander, because the typical lieutenant commander standing TAO watch "didn't want to be responsible for…big decisions." If permission was granted by the commander, the Battle Force staff would then have to contact the carrier, initiating a new process that would itself take a number of minutes. Moreover, the process might take even longer than usual because the carrier was about to launch other aircraft. *Find conflict:* The AAWC's expectations regarding the standard procedure conflicted with the *purpose* of timely, proactive response to the missile site.

Resolve conflict by adopting an assumption: Even now, the AAWC was not ready to abandon the initial recognitional response. To defend the standard procedure in the face of this problem, the AAWC tried to construct the best possible story; in effect, the AAWC imagined that the standard procedure was a success, and asked how that could be. The AAWC concluded that for the standard option to be acceptable, he would have to assume that the Iraqi missile site had switched on its fire control radar without the intent to launch a missile. *Evaluate the assumption:* While this was possible (for one thing, they had previously launched a missile without turning on their radar in advance), it was certainly not guaranteed. To assume the enemy would not fire meant adopting a *predictive* time orientation, which depends on assumptions about what the enemy will do, rather than a *proactive* orientation, which influences what the enemy can do. He was not comfortable with this assumption either. *Quick test*: The AAWC chose not to consider enemy intent any further. Taking more time to think critically about enemy intent was unnecessary in this situation. [It is worth noting that this judgment contrasts sharply with the behavior we have observed in non-wartime or low intensity conflict situations, where inferring hostile intent can play a major role in the decision to engage a target. In the latter situations, officers use critical thinking to fill gaps and resolve conflicts in an *enemy intent* mental model, and often consider *alternative possible causes and effects* of an unexpected and possibly hostile enemy action. Thus, critical thinking focuses on different mental models in different circumstances. See Cohen et al., 1996.]

Resolve conflict by finding another option: The Anti-Air Warfare Coordinator voiced misgivings to his own staff, including an Air Intercept Coordinator (AIC) whom he regarded as "outstanding." The AIC suggested another option just as the AAWC was thinking of it himself: An Armed Surface Reconnaissance (ASR) plane already in the air might be able to take out the missile site. *Quick Test:* This option also was subjected to critical scrutiny, since it was a departure from standard procedure. This option, too, was not without problems.

<u>Critiquing the new option</u>

Fill gap by collecting information: One problem was immediately apparent: Was the ASR well enough armed to carry out this unusual mission, and was it willing to do so? The AAWC and AIC contacted the ASR to find out, and the ASR crew responded that they could and would undertake the mission. *Find conflict:* A second problem had to do with the violation of standard operating procedures: A reconnaissance aircraft had never before been used under the control of an Anti-Air Warfare officer for a ground strike mission. *Resolve conflict by adopting assumption:* The AAWC chose to assume that he had the authority to retask the ASR, since he was the officer in control of the airspace. *Evaluate the assumption:* The AAWC was comfortable with this assumption. The Captain of his cruiser had established an atmosphere that encouraged initiative: "If I had a different kind of captain that had a different type of mentality…I might not have made that decision."

Find another conflict: The normal procedure would be to refer the decision regarding use of the ASR to his own TAO. Again drawing on knowledge of *team member reliability*, however, the AAWC figured that his TAO "didn't make aggressive decisions…if it wasn't something that had happened before." *Resolve conflict by modifying the option:* Instead, he announced what he was going to do, and his TAO "went along with it." The AAWC adopted a *proactive* orientation with respect to his superior, influencing rather than soliciting his decision.

Find another conflict: The TAO, nonetheless, called the Battle Force staff to inform them of the decision, and they said to wait. The TAO told the AAWC that Battle Force staff wanted to determine if any friendly troops were in the area of the Iraqi missile site. This created a new problem: The ASR had just radioed the AIC and AAWC that it was low on fuel and would have to strike the missile site immediately or else return to base. There was no time to wait for the Battle Force staff to close the loop. *Resolve conflict by finding another option:* The AAWC briefly considered waiting for the ASR's replacement, an S-3 aircraft, to become airborne. *Find conflict:* However this presented similar problems that, if anything, were worse than the problems with using the ASR: Taking control of the S-3 would require too much time. Moreover, the S-3 had more explicit restrictions on its use than the ASR, which would take even more time to work around. *Quick Test:* The AAWC did not think it worthwhile to further consider this option.

Resolve conflict by modifying the option: The AAWC now considered the possibility of acting prior to receiving clearance from the Battle Force. He would again be adopting a *proactive* orientation toward a superior, by denying the Battle Force Commander the option of preventing use of the ASR. *Find conflict*: But were there friendlies in the area (i.e., was the Battle Force concern valid)? *Resolve conflict by retrieving information:* In deciding whether to use the ASR without clearance, the AAWC drew on knowledge of the *task situation*. He thought it extremely unlikely that any friendly forces would be in the area of the missile site, since he had been sending attack missions into that area all day. *Continue to resolve conflict by collecting information:* Because the cost of an error was high, the AAWC chose to verity this further by calling staff on the battleship Missouri, who confirmed that no friendlies were in the area.

Continue to resolve conflict by adopting assumption: It seemed reasonable to conclude that no friendlies were in the area, but why then was the Battle Force staff reluctant to approve use of the ASR? The AAWC drew again on knowledge of *team member reliability*. Based on past experience, the AAWC felt that the Battle Force staff was overly cautious in general. All the signs indicated that the Battle Force would eventually give its approval. He also concluded that if they did deny permission to send the ASR, that decision would be based on caution rather than on safety-related information. Acting prior to clearance was thus *predictive* with respect to his superior's eventual approval, but proactive with respect to his superior's real options. *Evaluate assumption*: The AAWC resolved the conflict by assuming that approval would eventually come, but accepting that he would have to "take the hit on being too aggressive" if permission were denied. He was comfortable with accepting this risk. By contrast, following the standard procedure required a predictive orientation to the enemy, based on assumptions he was far less comfortable with: that the enemy missile site would not fire, or that the carrier launch process would come off more accurately and quickly than before.

Taking action

The AAWC told the TAO what he was going to do, then tasked the ASR to strike the missile site. The site was successfully destroyed. Clearance from the Battle Group

Commander arrived shortly thereafter. The AAWC and TAO waited a few minutes, then reported the destruction of the missile site to the commander. They received commendation for their action, and use of the ASR in this way became a new standard operating procedure in the battle force. The Battle Force commander never knew that the AAWC had acted on his own initiative before receiving clearance.

Discussion

In this example, taking initiative with respect to the enemy required taking initiative within the organization, and both required critical thinking. Critical thinking that focused on mental models of *action sequence*, *rate of movement*, *team member reliability*, and *purpose* enabled the AAWC to identify problems with the standard procedure. In particular, he saw that it implied a predictive rather than a proactive stance in the face of an unexpected enemy action (turning on its radar), and thus did not sufficiently reduce uncertainty about enemy action in the future (firing a missile). The desire to be proactive toward the enemy, in turn, was the source of the time pressure that influenced the AAWC's subsequent decision making. In that decision making, he drew on critical thinking about mental models to decide (i) whether to communicate, (ii) how to coordinate without communication, and (iii) how to evaluate communications that did occur. These are, of course, the issues identified earlier as characteristic of time-stressed, novel, and spatially distributed situations. The AAWC's way of handling these issues involved each of the three time orientations:

(1) *Should we communicate?* Through critical thinking, the AAWC decided not to wait for closed-loop communication with the Battle Force commander. Waiting would have entailed an unacceptable loss of initiative with respect to the enemy. Instead, he chose to be *proactive* both with respect to the enemy and with respect to the Battle Force commander (and his own TAO). Consistent with Figure 2, the key mental models in this critical thinking process were friendly *purpose* (to prevent damage to the battle group by the missile site), and shaping both *enemy intent* and *friendly intent* (i.e., eliminating options).

(2) *What will the others do?* On the other hand, the AAWC also used critical thinking to achieve as much coordination as possible despite the lack of full communication, through a *predictive* time orientation. For example, he predicted that the standard procedure would not accomplish a strike on the missile with the required accuracy or speed. He also predicted with some confidence that friendly forces would not be in the area of the target. He predicted that the TAO would go along with the decision presented to him, and that the Battle Force commander would ultimately approve the strike on the missile site. Again consistent with Figure 2, the key mental models were *friendly intent*, team member *reliability* and the *rate of movement* (i.e., likely duration) of a friendly *action sequence*.

(3) *How good is the information?* Finally, the AAWC used critical thinking to evaluate the information that was communicated to him and to *react* appropriately to it. For example, he considered alternative hypotheses about the intent of the enemy in turning on the missile site radar. He interpreted the hesitation of the TAO and the Battle Force staff as indicators of habitual caution rather than as signs of actual disapproval or risk. By contrast, he assigned greater credibility to the opinions of the AIC and the staff of the battleship Missouri, both of whom he regarded as more likely to favor decisive

action in regard to the enemy. Again consistent with Figure 2, the key mental models were *alternative causes and effects* and team member *reliability*.

By means of critical thinking, the AAWC was able to develop proactive tactics both toward the enemy and toward his own organization. In doing so, he developed a mutually supporting framework of proactive, predictive, and reactive orientations toward different aspects of the task. He invested a small amount of time thinking in order to buy much more time for action. The long-term result was improved adaptation to environmental variability *at the organization level*.

TRAINING FOR INITIATIVE

How should critical thinking skills be trained? Different conceptions of decision making skill are associated with different training strategies. For example, if decision making skill is regarded as a small set of general-purpose techniques (Baron & Brown, 1991), critical thinking can be taught as a subject in its own right, distinct from the various specialized domains in which it is applied. The primary method of training, from this point of view, is typically explicit classroom instruction, with examples of decision problems playing a secondary role for motivation and practice (e.g., Adams & Deehrer, 1991). At the opposite extreme, if decision making skill is regarded as pattern matching, critical thinking cannot be identified as a subject matter by itself. Training should be fully infused into the regular curriculum for each specific subject area . This training will focus primarily on practice with numerous realistic and typical examples of decision problems and their solutions, with very little explicit instruction (Means, Salas, Crandall, & Jacobs, 1993).

The approach to training based on the Recognition / Metacognition model is distinct from both of these. The content of critical thinking training is not a small set of general-purpose methods nor is it a vast quantity of specialized patterns and responses. The focus is on a moderately sized set of mental model types (including time orientations) and critical thinking strategies that critique and correct them. Unlike specialized patterns, both the mental models and the thinking strategies are generalizable (in many if not all respects) from one domain to another, especially domains characterized by uncertainty about human action within and outside an organization and by time constraints. But there is a problem with *teaching* critical thinking as a general purpose methodology, even if it can be broken down into a moderately sized set of mental models and strategies. To the extent that critical thinking is *meta-recognitional*, it can be effectively exercised only within a domain that is familiar enough for there to be significant recognitional knowledge. The domain must also be familiar enough for the creative exploration of a rich knowledge base, for example, in the identification of assumptions and the development of alternative conclusions. Thus, critical thinking might best be taught as *a separate module (or set of modules)*, because there are reasonably general critical thinking principles, but *within a specific subject matter area*, because critical thinking cannot be exercised effectively without pre-existing knowledge. Training involves a combination of explicit presentation of critical thinking concepts followed by intensive practice and feedback in realistic, challenging, but not necessarily typical scenarios.

Training based on this approach has been developed and successfully tested in Navy and Army tactical decision making environments. The training is based on empirical research, such as that described above, on differences in mental models and thinking strategies between more and less experienced decision makers in real-world problems. Most recently, we have developed a computer-based interactive training program for Army battlefield critical thinking, packaged as a stand-alone CD that runs under Microsoft Windows, and that can also be accessed by a browser on the World Wide Web. The program, which is called MEntalMOdeler, or MEMO, uses graphical interactive techniques to present concepts and provide practice and feedback. MEMO has recently been assigned and evaluated in an advanced tactics course at the Army Command and General Staff College (Center of Army Tactics), Leavenworth, KA.

The training teaches students the elements of initiative, focusing on how to think critically about *purpose*, *time*, and *uncertainty*. It includes four major segments. The first segment contains an introduction to the mental models that represent purpose, followed by a second segment on thinking critically about those mental models. The third segment addresses the mental models that represent time orientation (i.e., influencing, predicting, or reacting to another agent), followed by a fourth segment on how to think critically about those mental models. Each of these segments contains an introduction to the relevant concepts using both verbal and graphical methods, military examples of how the concepts apply, historical case studies that illustrate the concepts, and interactive exercises with feedback. The training increases in difficulty as it progresses through these four segments. A final, fifth segment applies the mental model and critical thinking concepts to so-called “maneuver warfare” and “attrition” tactics.

All exercises involve relatively realistic (though brief) military scenarios adapted from the Tactical Decision Games feature published monthly in the *Marine Corps Gazette* (see also Schmitt, 1994). Each of the scenarios selected for use in the exercises addresses the issue of initiative in a context of uncertainty, time stress, and limited communication.

Segment 1: Purpose

Focus on purpose increases with experience and is closely associated with the ability to adopt a proactive time orientation (see Figure 2). This section of the training, which is the simplest, gives students conceptual and graphical tools for organizing their thinking about purpose. The main points of the section are (i) that thinking about the situation and about one’s own plans should always be guided by an understanding of purpose, and (ii) purpose is not simply the immediate mission of your part of the organization, but includes the purposes of adjacent and superior units. Purpose in this higher-level, longer range sense provides the big picture within which critical thinking takes place.

The section starts by reviewing a graphical tool, called a *nesting diagram*, that shows *why* your own unit has the purposes and tasks that are assigned to it, in terms of its relationships to purposes and tasks of adjacent units and superior units two or more levels up. A nesting diagram shows which units are assigned the main effort of their superior unit and which adjacent units are tasked to support those efforts. The training provides practical guidance on how to extract elements of the nesting diagram from an operations order received from superior headquarters, and contains exercises on constructing such diagrams in both simple and complex cases (e.g., missing information, purposes not lined up with the organizational hierarchy). Many students are already somewhat familiar with nesting diagrams, and they thus provide a good entry point for understanding mental models.

The next section generalizes the idea of a *mental model* beyond nesting diagrams. A mental model is defined as a succinct summary of events or ideas, which shows how each event or idea is linked to success or failure of your purpose. Mental models, which can be verbal or graphical, provide a tool by means of which decision makers stay focused on purpose as their thinking evolves through stages of the decision making process. Upon receipt of the mission, the command staff creates a nesting diagram placing their own unit in the larger context of the operation. Planning starts with this nesting diagram and asks *how* the various purposes it represents can best be achieved. The initial answer to this question is the commander's guidance or intent, which states how the purposes of the unit will be achieved in the present situation. Subsequently, during course of action development, the mental model is elaborated in still more detail, to provide a concept of operations. Later, during course of action analysis, the mental model takes the form of a detailed synchronization matrix, coordinating activities of different subordinate units at different places and times. This section of the training emphasizes diagrammatically how all these stages of mental model development are linked to one another and to the unit's purposes.

The next section begins the discussion (which will continue through the rest of the training) of how mental models are used to make decisions. It emphasizes the importance of considering higher-level purposes. A plan that is designed to achieve a unit's immediate purpose may be inadequate if it does not also put the unit in a position to provide back-up for adjacent and superior units, and to assume their tasks in the case of the unexpected.

Segment 2: Critical thinking about purpose

This section provides an overview, examples, and exercises for the critical thinking process, called *I.D.E.A.S.* (an acronym for *Identify, Deconflict, Evaluate, Act,* and *Stop*), based on the model in Figure 3. The first three steps (*Identify, Deconflict,* and *Evaluate*) correspond to critiquing for the three kinds of uncertainty identified in our research: gaps, conflict, and unreliable assumptions. More specifically, the first step is to identify and fill gaps in mental models, i.e., missing components of the plan or of one's situation understanding that are likely to have an impact on the achievement of purposes. The second step is to identify and resolve conflicts between information sources or goals. The third step is to find and evaluate assumptions in the current plan or situation model. *Act* represents the different correcting strategies that can be adopted to address those problems and to improve the situation model or plan. *Stop* stands for the Quick Test, which weighs the benefits of continued critical thinking against its costs and determines when it is necessary to take action based on the best current solution.

These steps are discussed by means of examples from both planning and real-time operations. Filling gaps in a plan leads to discovery of a conflict between optimal achievement of the immediate purpose of the unit and providing back-up for higher-level purposes. A variety of correcting steps are illustrated and evaluated: e.g., collecting more information to confirm or disconfirm the likelihood that other units will need back-up, adding a branch or contingency to the existing plan in case of unexpected events, changing the current plan to provide more flexibility, or accepting the risk that nothing will go wrong for other units. During the operational phase of the plan decision makers not only monitor progress in achieving their own goals, but also monitor the success or failure of other units in achieving their goals. When unexpected events during an operation occur, an immediate decision must be made on how and what to communicate, and whether to continue on the original task or to shift the focus of effort.

An interactive exercise requires students to critique and modify a plan in the face of surprising events. Feedback is given, and then a new variant of the plan is provided that addresses shortcomings of the previous option. The students must then critique and modify the new option. Feedback is again given, along with yet another variant of the plan to be critiqued and corrected. A historical example of initiative is also provided, involving U.S. Grant at Vicksburg. Attention to higher-level purposes led General Grant to abandon his line of communications, modify virtually every part of his orders, and still achieve one of the pivotal victories of the Civil War.

A final topic on critical thinking about purpose focuses on ferreting out hidden assumptions, by means of a devil's advocate strategy. This strategy involves imagining that a crucial assessment or plan will fail to achieve its purpose(s), and forcing oneself to explain how that could happen. Students learn to stimulate their imagination by picturing an infallible crystal ball that persistently tells them their explanations of the failure are wrong, and demands that they generate another one. They also learn to use their mental models in conjunction with the crystal ball to identify points where failure could occur. An interactive exercise asks that they use this technique to find and resolve problems in a tactical scenario.

Segment 3: Time orientation

The next major segment of the training involves *time orientation*, i.e., putting purposes to work in a framework of time and action. In the first section, the training extends the graphical mental modeling tools introduced in the previous segment, by adding a horizontal time dimension to represent a sequence of events and actions (the vertical dimension continues to represent the hierarchy of purposes). *Initiative* is discussed in terms of mental models that show how friendly actions can influence, predict, or react to the decision cycle of the enemy or other friendly units. The three time orientations – proactive, predictive, and reactive – are explained in terms of how and when they reduce uncertainty about another agent's actions.

The next section of this segment introduces the use of time orientation models to make decisions. It describes the questions that need to be asked to fill gaps in reactive, predictive, and proactive mental models. To create a predictive model, for example, the decision maker asks: "What will the enemy do and what strengths or weaknesses are associated with those actions? What are the implications of those strengths and weaknesses for my purposes? And what can I do to avoid the strengths or exploit the weaknesses?" To create a proactive mental model, on the other hand, the decision maker asks: "What are my higher purposes? What do I *want* the enemy to do that will promote those purposes? And what can I do to get him to do it?" An interactive exercise requires students to identify the time orientations implicit in different strategic, operational, and tactical plans during Operation Desert Storm.

Segment 4: Critical thinking about time orientation

This segment introduces students to a more sophisticated set of critical thinking strategies, and to a deeper understanding of how proactive, predictive, and reactive orientations can co-exist in a single mental model. The first section discusses how correcting one kind of problem can lead to other problems across cycles of critiquing and correcting. The primary emphasis is on how each time orientation can be used to address weaknesses in the other time orientations, as plans are gradually elaborated and improved, and that the most effective plans ultimately involve several time orientations in a mutually supporting pattern.

The next section provides a detailed example of the evolution of a plan through the I.D.E.A.S. cycle, and illustrates a simple multiple time-orientation pattern. Planning begins with a predictive model, in particular, a plan based on the expectation that an enemy unit will cross a river and be vulnerable to attack as it crosses. A devil's advocate strategy is then used to critique the plan. (An infallible crystal ball says, "The plan will fail. Explain how.") This process brings to light hidden assumptions about enemy intent upon which the plan depends. To make the plan more robust, proactive tactics are developed to lure the enemy across the river. Other proactive tactics are developed to increase the enemy's vulnerability while crossing by using artillery to prevent it from concentrating forces. To guard against the possibility that predictive and proactive tactics fail to achieve their purpose, the plan is further elaborated to include monitoring of enemy movements and a flexible, reactive orientation in case the enemy does something other than what is expected. The result is a template in which different time orientations provide mutual support: Proactive tactics are utilized to increase the chance that predictive assumptions will turn out to be true, while reactive tactics monitor for the unexpected.

In a continuation of this example, the enemy does in fact behave in a surprising manner (heading in a different direction than expected). A new template for mutually supporting time orientations is illustrated. The initial reaction is designed to mitigate any immediate threat from the enemy action. The next phase is to consider any enemy weaknesses that the action exposes or creates (e.g., failing to cross the river leaves a command post relatively undefended on the other side). These weaknesses are, ideally, independent of specific assumptions about what the enemy is up to. Predictive tactics are developed to exploit opportunities that are identified. At the same time, a way is sought to use these opportunities to *create* new weaknesses, i.e., to proactively degrade the enemy's capability to pursue *future* operations (e.g., by destroying a command post, or attacking logistics). The result of this critical thinking process is a template for reaction to surprise that shifts as rapidly as possible from reactive to predictive to proactive orientations.

Two historical examples of reaction to surprise are described, in both of which unexpected enemy action was turned to friendly advantage: U.S. Grant at Fort Donelson, and Eisenhower in the Ardennes offensive. An interactive exercise requires students to identify the combinations of time orientations represented by the small unit tactics described in James McDonough's book, *Platoon Leader*.

Segment 5: Applications to initiative-oriented fighting

This segment of the training applies the above lessons to current discussion of Army tactics. It continues to focus on critical thinking about time orientation, but gives special attention to issues raised by proponents of *maneuver warfare*, which focuses on initiative (Hooker, 1993; Lind, 1985; The United States Marine Corps, 1989; Leonhard, 1991, 1994). The first section clarifies the difference between maneuver and attrition methods by the use of diagrammatic mental models depicting all three time orientations: (1) *Reactive*: Attrition emphasizes taking time to prepare, while maneuver emphasizes the ability to react quickly and flexibly to events by local commanders on the spot. (2) *Predictive*: Attrition emphasizes predicting and attacking enemy strength, while maneuver emphasizes predicting and attacking enemy weakness. (3) *Proactive*: Attrition destroys the enemy's assets in order to gradually wear down its ability to fight and limit its future options, while maneuver tries to generate moral effects, like shock and panic, which reduce the ability of enemy to make decisions at all and can lead to a sudden enemy collapse.

The next section shows how maneuver tactics draw on a highly interdependent system of mutual supports among time orientations. A series of graphical time orientation templates is presented to depict these relationships. For example, the tactics of "surfaces and gaps" involves mutual support between rapid reaction and prediction of enemy weakness. Friendly forces probe in many locations for weaknesses (or "gaps") in enemy front lines, and take initiative in order to react rapidly to any success, by sending reserves through the gaps into the enemy rear. If this *reaction* is rapid enough, the enemy will be *predicted* to be unable to repair the breach in time to prevent the exploitation. At the same time, attacking predicted enemy weakness makes speed possible by avoiding unnecessary fights. Thus, reactive and predictive orientations support one another.

Predictive and proactive orientations are even more closely intertwined in maneuver warfare. The objective of the exploitation of gaps is *proactive*: to reach the enemy rear and strike a high-leverage enemy vulnerability, typically command and control or logistics, without which the enemy cannot continue to fight. This objective is *predicted* to be relatively lightly defended by virtue of being in the rear, and the rapidity of the attack is also expected to prevent any redeployment of enemy forces for its defense. In addition, the predictive aspects of this action can provide an important *proactive* byproduct: By attacking suddenly in an area thought to be safe, friendly forces can cause the enemy to panic. This panic will proactively degrade the enemy's ability to continue the fight as much as the actual loss of command and control or logistics. These proactive effects in combination create new weaknesses that can be further exploited by predictive actions.

In short, the essence of maneuver warfare is the snowballing, positive feedback effects that it strives to create among the three time orientations. Autonomous decision making by low-level units is crucial for the required rapidity of response that gets the process going. The purpose is to win as quickly as possible, at the least cost. An interactive exercise requires students to apply maneuver warfare concepts in the process of critical thinking about courses of action.

The next section in this segment explores critical thinking about maneuver warfare tactics more closely. It examines some of the problems to which highly initiative-oriented maneuver tactics can lead. (1) Reactive and predictive orientations can conflict, for example, if speedy reactions leave units with unprotected flanks. This is an example of a more general problem with taking initiative in the absence of complete communication or advance coordination. Assumptions must be made about the actions taken, or the success realized, by other friendly units, and these risks must be weighed against the potential advantages of quick reaction. (2) Predictive and proactive orientations can conflict if normally high-leverage targets, such as command and control and logistics, are in fact not weakly defended. A greater emphasis on preparation and coordination rather than tempo and surprise may be required when this is the case. (3) Maneuver tactics use all three time orientations to compensate for lack of coordination among friendly units: by rapidly reacting to signs of existing enemy weaknesses, by exploiting them before the enemy can respond, and by creating new enemy weaknesses through high tempo and surprise and by striking high-leverage targets. Success on all these fronts depends on a number of assumptions: that rapid movement can be executed given the terrain, weather, equipment, and enemy resistance; that predictions about weakness are correct, e.g., that apparent gaps in enemy front lines are real rather than traps laid by the enemy; that shock tactics will have the intended psychological effects on this particular foe, causing them to collapse rather than hunker down; and that the enemy really does depend critically on the targeted command and control and logistics capabilities. Failure of these assumptions can turn promising initiative into disaster. Students get practice making these kinds of tradeoffs in exercises in which high levels of initiative involve a cost in communication and coordination

LESSONS LEARNED: TRAINING INITIATIVE IN TEAMS

Lesson 1: Initiative is vital in team performance

Initiative is an important but neglected topic in team decision making and team training. It is a vital ingredient in situations characterized by unexpected and rapidly unfolding dangers or opportunities, and where communication is limited by spatial separation, workload, specialization of knowledge, or other factors. In such environments, leadership initiative and responsibility devolves upon teams and individuals that are ordinarily subordinate, but who are able to act more quickly and effectively on the spot. These individuals and teams need training that enables them to discriminate situations where initiative is appropriate, from other situations where coordination and communication are more important (e.g., when many sources of information must be integrated, large-scale patterns of events must be interpreted, and actions must be coordinated across the organization). When initiative is appropriate, teams and individuals need to learn when and how to communicate, how to anticipate actions of other friendly units, and how to interpret information that is communicated by other friendly units.

Lesson 2: Training can be based on differences between more and less experienced decision makers in real-world situations

Development of training content for a particular domain can be based on analysis of interviews in which decision makers describe actual experiences in challenging, real-world situations. This approach reveals important differences between more and less experienced decision makers in both the knowledge they draw upon (mental models) and the thinking strategies they employ. These differences can become the focus of effective training for initiative in that domain. Moreover, there is reason to suspect that key aspects of that training will transfer across domains, such as the importance of purpose, time, and critical thinking.

Lesson 3: Awareness of purpose is a key ingredient of initiative

An important difference between more and less experienced decision makers is focus on higher-level and longer-term purposes or general principles. In non-routine situations, experienced decision makers work to clarify goals, and to modify and elaborate them if necessary. This understanding of purpose is then used to guide attention to the most critical features of the situation and to construct or select actions. Attention to purpose correlates both with experience and with the degree of initiative shown by decision makers. Attention to purpose also plays a role in *creativity* or innovation. Creativity often involves questioning or disregarding traditional, lower level goals, habits, and constraints and focusing on new ways to achieve what the organization truly values (Ray & Myers, 1986).

Lesson 4: Appropriate time orientation is a key ingredient of initiative

Another important difference associated with experience involves time orientation. Experienced decision makers make greater use of proactive strategies, and therefore take more initiative. Proactive decision makers influence the decisions of other agents (e.g., enemies, competitors, superiors, or colleagues) rather than simply predict or react to their actions. Time orientation in turn helps determine the knowledge or mental models decision makers draw upon. Nor surprisingly, the proactive orientation is closely associated with attention to higher-level purpose. Both proactive and predictive orientations draw on mental models of intent. Both predictive and reactive orientations draw on models of team member reliability. Finally, all three orientations draw on knowledge of the sequence of actions in a task.

Lesson 5: Critical thinking processes are a key ingredient of initiative

Critical incident interviews and other research suggests that a variety of critical thinking strategies also develop with experience. These skills supplement and improve pattern recognition skills rather than replacing them with formal decision making methods. Experienced decision makers learn to verify their initial recognitional response when the stakes are high, time is available, and the situation is unfamiliar or uncertain. They learn to flesh out their understanding of a hypothesis or action by recalling or collecting relevant information. They learn to notice conflicts, in which observations fail to match familiar patterns, and standard responses are not likely to achieve desired purposes. When conflict is found, instead of immediately rejecting the recognitional conclusion, they tend to patch it up by generating a story that explains the conflict. They then evaluate the assumptions required by the story, and accept, modify, or reject the conclusion based on that evaluation. For decision makers armed with these skills, initiative is the result of careful scrutiny of the standard response; the decision to deviate from it is made with full awareness of the assumptions and risks involved.

Meta-recognitional processes can be understood in terms of the intelligent shifting of attention to activate additional knowledge in the recognitional system, and the persistent application of attention to hypothetical contingencies in order to conduct what-if reasoning. Here again, there is a suggestive link to research findings on creativity. Creative thinking involves inhibiting routine responses, letting attention roam beyond the immediate associations in the situation, and challenging assumptions.

Lesson 6: Training for initiative should include a focus on purpose, time orientation, and critical thinking

A strategy method has been developed for Army battlefield decision making skills that focuses on these three key ingredients of initiative: purpose, time orientation, and critical thinking. The strategy trains less experienced decision makers to use both the knowledge structures and decision making strategies characteristic of more experienced decision makers. The training has five segments: purpose, critical thinking about purpose, time orientation, critical thinking about time orientation, and more advanced issues in deciding when to take initiative.

The training (in a previous, non-automated version) has been tested with active-duty officers in Army posts and schools around the country, and it works (Cohen, Freeman, Fallesen, Marvin, & Bresnick, 1995; Cohen, Freeman, Wolf, & Militello, 1995). A short period of training, both in Army and Navy contexts, has been consistently found to produce significantly better combat decisions, as judged by experienced officers. In addition, trained participants were able to consider a wider range of factors in making a decision, identify more evidence that conflicted with their initial recognitional response, identify more assumptions, and generate more alternative options than untrained participants.

A computer-based version of the training was enthusiastically received by the dean of the Command & General Staff College and the director of the Center for Army Tactics at the Army Command and General Staff College, Leavenworth, KA. CGSC instructors in several different courses have expressed an interest in using the material, and it has already been used in one advanced tactics course. Preliminary evaluation of the latter suggests that the training helped students identify more assumptions and adopt more robust plans in test scenarios.

Lesson 7: Training should combine instruction, examples, practice, and feedback

The computer-based version of the training is accessible either through CD-ROM or over the World Wide Web, and will be suitable for classroom instruction, training in the field, or distance learning. The combination of techniques utilized in this system reinforces learning and seems to successfully accommodate differing student learning styles. For example, some student comments stressed the value of the explicit instruction, while other comments stressed the value of actual examples from military history. Most students appreciated the interactive exercises and expressed a desire for more.

Future Directions

This chapter has focused on an important role of critical thinking in teamwork: how it is used to balance the benefits of initiative against those of coordination in uncertain, dynamic situations. There are many open questions and avenues for further research. Here are just a few, regarding teams, organizations, individuals, and training:

Teams. What role does critical thinking play in other aspects of teamwork, such as planning, mutual monitoring, backup, feedback, and load leveling? How are critical thinking styles and mental models related to leadership styles, such as autocratic versus consultative (Yukl, 1998), or concern for people versus concern for performance (i.e., the “managerial grid,” described in Foushee & Helmreich, 1988)? Answers to these questions might lead to improved training of teamwork behaviors.

Organizations. What role does critical thinking play in larger organizations? For example, there is often a tradeoff in such organizations between risky exploration of new possibilities and the short-term certainty of building up competence and reaping the benefits of existing products and ideas (March, 1996). This is at least superficially analogous to the tradeoff between initiative and coordination in teams, and we may wish to study the role of critical thinking about mental models in decisions about allocating resources to research, decentralization versus centralization of organizational structure, receptivity to innovation, introduction of new products, and infusion of personnel from outside the organization. How do leaders and/or followers use critical thinking to adapt their organizations structurally and functionally in changing task environments? Are different critical thinking skills and types of mental models required at different levels of leadership in an organization, as suggested by Jaques & Clement (1994)?

Individuals. Individuals face an analogous tradeoff in the decision of whether or not to think critically at all. Leaders at every level must find a balance between rapid responding based on readily retrieved information and more time-consuming reflective processes that may lead to something new. Do people differ in their bias for recognition versus reflection, i.e., do people differ in *impulsivity – reflectivity* (Messer, 1976)? How do variations in this cognitive style dimension affect leadership? What variables determine the appropriate balance between impulsivity and reflectivity, and do they include organizational level? Are there more subtle individual differences in style of critical thinking? For example, can individuals who are equally prone to critical thinking differ in the emphasis they place on improving existing ideas versus finding radically new ones? Can *creativity* itself be understood at least in part as a style of critical thinking involving, for example, relatively unconstrained search for alternatives?[6]

Training. We asked earlier, How should critical thinking be trained? This issue should be revisited in light of its links to individual cognitive styles, on the one hand, and organizational variables, on the other. Can critical thinking training be made robust enough to stand on its own, as a separate subject matter, by focusing on broad cognitive styles and attitudes? Such styles and attitudes might generalize across domains and situations more readily than specific strategies (Baron, 1994; King & Kitchener, 1994). On the other hand, do cognitive styles and attitudes themselves vary significantly from one organizational context to another, as we suspect they do? If so, critical thinking might best be taught as a separate module but within a specific subject matter and organizational level. The latter is the approach illustrated in the present chapter.

Although these questions remain open, they do not preclude tentative conclusions in the light of what is already known: There are many areas of practical life where team performance will be improved by enhancing the ability of team members to judge when, where, and how to take the initiative.

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[6] A compelling case can be made that critical thinking and creativity are inseparable aspects of thinking. Bailin (1990) and Paul (1987) argue that critical judgment is necessary for creativity; e.g., to recognize the inadequacy of existing solutions and decide that a new approach is required (sometimes as part of an extended process of questioning and doubting authority), to determine directions for investigation, and to evaluate the products of creativity. Conversely, it has been implicit throughout this chapter that creativity is a part of critical thinking, even when it leads only to modification rather than replacement of the existing solution. As Bailin points out, critical thinking requires many non-algorithmic and non-analytic processes, such as identification of background assumptions in an argument, visualizing potential problems with your own position, empathetically imagining alternative positions, and arriving at an overall assessment.

ACKNOWLEDGMENTS

This work was sponsored by the Army Research Institute under Contract No. DASW01-97-C-0038 with Cognitive Technologies, Inc.. We are grateful to the COTR, Sharon Riedel, for her many contributions, and to the important contributions of Len Adelman, Terry Bresnick, General Bill Richardson, and General Joe Mead throughout the project. Thanks to Colonel Tystad and Lieutenant Colonel Hewitt of the Command and General Staff College, Leavenworth, KA, for their cooperation, and to Lieutenant Colonel Billy Hadfield for his active participation in the development and evaluation of the training.

REFERENCES

Adams, M. J. & Feehrer, C. E. (1991). Thinking and Decision Making. In J. Baron & R. V. Brown (Eds.), Teaching Decision Making to Adolescents (pp. 79-94). Hillsdale, NJ: Erlbaum.

Adelson, B. (1984). When novices surpass experts: The difficulty of a task may increase with expertise. Journal of Experimental Psychology: Learning, Memory, and Cognition, 10(3), 484-495.

Anzai, Y. (1991). Learning and use of representations for physics expertise. In K. A. Ericsson & J. Smith (Eds.), Toward a general theory of expertise (pp. 64-92). Cambridge: Cambridge University Press.

Bailin, S. (1990). Argument criticism as creative. In R. Trapp & J. Schuetz (Eds.), Perspectives on argumentation. Prospect Heights, IL: Waveland Press.

Baron, J. (1994). Thinking and deciding. Cambridge: Cambridge University Press.

Baron, J. & Brown, R. V. (Eds.). (1991). Teaching Decision Making to Adolescents. Hillsdale, NJ: Erlbaum.

Blau, P.M. (1970). A formal theory of differentiation in organizations. American Sociological Review, 35, 201-218.

Brown, Lesley (Ed.). (1993) The New Shorter Oxford English Dictionary. Oxford: Clarendon Press.

Burns, T., & Stalker, G. M. (1962). The management of innovation. London: Tavistock.

Cannon-Bowers, J. A., Salas, E., & Converse, S. (1993). Shared mental models in expert team decision making. In N. J. Castellan (Ed.), Individual and group decision making (pp. 221-246). Hillsdale, NJ: Lawrence Erlbaum Associates.

Cannon-Bowers, J. A., Tannenbaum, S. I., Salas, E., & Volpe, C. E. (1995). Defining competencies and establishing team training requirements. In R.A. Guzzo, E. Salas, & Associates (Eds.), Team effectiveness and decision making in organizations (pp. 333-380). San Francisco: Jossey-Bass Publishers.

Chase, W. G., & Simon, H. A. (1973). The mind's eye in chess. In W. G. Chase (Ed.), Visual information processing (pp. 215-281). NY: Academic Press.

Castellan, N. J., Jr. (1993). Paradoxes in individual and group decision making: A plea for models. In N. J. Castellan (Ed.), Individual and group decision making (pp. 125-

134). Hillsdale, NJ: Lawrence Erlbaum Associates.

Chi, M., Bassock, M., Reimann, P., & Glaser, R. (1989). Self explanations: How students study and use examples in learning to solve problems. Cognitive Science, 13, 145-182.

Chi, M., Feltovich, P., & Glaser, R. (1981). Categorization and representation of physics problems by experts and novices. Cognitive Science, 5, 121-152.

Cohen, M. S. (1986). An expert system framework for non-monotonic reasoning about probabilistic assumptions. In J. F. Lemmer & L. N. Kanal (Eds.), Uncertainty in artificial intelligence (pp. 279-293). Amsterdam: North-Holland Publishing Co.

Cohen, M. S. (1993). The naturalistic basis of decision biases. In G. A. Klein, J. Orasanu, R. Calderwood, & C. E. Zsambok (Eds.), Decision making in action: Models and methods (pp. 51-99). Norwood, NJ: Ablex.

Cohen, M.S., Freeman, J.T., Fallesen, J. J., Marvin, F., and Bresnick, T. A. (1995). Training critical thinking skills for battlefield situation assessment: An experimental test. Arlington, VA: Cognitive Technologies, Inc..

Cohen, M.S., Freeman, J.T., & Thompson, B.B. (1998). Critical thinking skills in tactical decision making: A model and a training method. In J. Canon-Bowers, & E. Salas (Eds.), Decision-making under stress: Implications for training & simulation. Washington, DC: American Psychological Association Publications.

Cohen, M.S., Freeman, J., Wolf, S.P., Militello, L. Training metacognitive skills in naval combat decision making. Arlington, VA: Cognitive Technologies, Inc., 1995.

Cohen, M. S., Freeman, J. T., & Wolf, S. (1996). Meta-recognition in time stressed decision making: Recognizing, critiquing, and correcting. Human Factors, 38 (2), pp. 206-219.

Cohen M. S., Parasuraman, R., Serfaty, D., & Andes, R.. (1997). Trust in Decision Aids: A Model and a Training Strategy. Arlington, VA: Cognitive Technologies, Inc.

Donaldson, Lex (1995). American anti-management theories of organization: A critique of paradigm proliferation. New York: The Cambridge University Press.

Doyle, J. (1979). A truth maintenance system. Artificial Intelligence, 12(3), 231-162.

Dreyfus, H. L. (1997). Intuitive, deliberative, and calculative models of expert performance. In C. E. Zsambok & G. Klein, (Eds.), Naturalistic decision making (pp. 17-28). Mahwah, NJ: Erlbaum.

Ellis, Ralph D. (1995). Questioning consciousness. Philadelphia: John Benjamins Publishing Company.

Ericsson, K. A., & Smith, J. (1991). Prospects And limits of the empirical study of expertise: an introduction. In K. A. Ericsson & J. Smith (Eds.), Toward a general theory of expertise. Cambridge: New York: University Press.

Forrest-Pressley, D. L., MacKinnon, G. E., & Waller, T. G. (Eds.) (1985). Metacognition, cognition, and human performance. NY: Academic Press.

Foushee, H. C., and Helmreich, R. L. (1988). Group interaction and flight crew performance. In E. L. Wiener and D. C. Nagel (Eds.) Human factors in aviation. San

Diego: Academic Press.

Glaser, Robert (1996). Changing the agency for learning: Acquiring expert performance. In K. A. Ericsson (Ed.), The road to excellence: The acquisition of expert performance in the arts and sciences, sports, and games. Mahwah, NJ: Lawrence Erlbaum Associates.

Halpern, D. F. (1996). Thought & knowledge: An introduction to critical thinking. Mahwah, NJ: Lawrence Erlbaum Associates.

Helmreich, R.L., & Foushee, H. C. (1993). Why crew resource management? Empirical and theoretical bases of human factors training in aviation. In E.L. Wiener, R.L. Helmreich, & B.G. Kanki (Eds.), Cockpit resource management. NY: Academic Press, Inc.

Holyoak, K. J. (1991). Symbolic connectionism: toward third-generation theories of expertise. In K. A. Ericsson & J. Smith (Eds.), Toward a general theory of expertise. Cambridge: New York: University Press.

Hooker, Richard D., Jr. (1993). Maneuver warfare: An anthology. Novata, CA: Presidio Press.

Janis, I.L. (1972). *Victims of groupthink*. Boston: Houghton Mifflin.

Jaques, E. & Clement, S. D. Executive leadership: A practical guide to managing complexity. Malden, MA: Blackwell Publishers.

Johnson, S.C. (1967). Hierarchical clustering schemes. Psychometrika, 32, 241-254.

Kaempf, G. L., Klein, G., Thordsen, M. L., & Wolf, S. (1996). Decision making in complex command-and-control environments. Human Factors, 38 (2).

Kerr, N.L. MacCoun, R.J. & Kramer, G. P. (1996). "When are N heads better (or worse) than one?": Biased judgment in individuals versus groups. In E. Witte & J.H. Davis, Understanding group behavior: Consensual action by small groups (Vol. 1). Mahwah, NJ: Lawrence Erlbaum Associates.

King, P. M. & Kitchener, K. S. Developing reflective judgment: Understanding and promoting intellectual growth and critical thinking in adolescents and adults. San Francisco: Jossey-Bass Publishers.

Klein, G. A. (1993). A Recognition-Primed Decision (RPD) model of rapid decision making. In G. A. Klein, J. Orasanu, R. Calderwood, & C. E. Zsambok (Eds.), Decision making in action: Models and methods (pp. 138-147). Norwood, NJ: Ablex.

Kleinman, D.L., & Serfaty, D. (1989). Team performance assessment in distributed decision making. In R. Gilson, J.P. Kincaid, & B. Goldiez (Eds.), Proceedings of the Interactive Networked Simulation for Training Conference. Orlando, FL: Naval Training Systems Center.

Kuhn, D., Amsel, E., & O'Loughlin, M. (1988). The development of scientific thinking skills. San Diego: Academic Press, Inc.

Kruskal, J.B. (1964). Nonmetric multidimensional scaling: A numerical method. Psychometrika, 29, 115-129.

Larkin, J.H. (1981). Enriching formal knowledge: A model for learning to solve textbook physics problems. In J. R. Anderson (Ed.), Cognitive skills and their acquisition (pp. 311-344). Hillsdale, NJ: Lawrence Erlbaum Associates.

Larkin, J., McDermott, J., Simon, D. P., & Simon, H.A. (1980). Expert and novice performance in solving physics problems. Science, 20(208), 1335-1342.

Leonhard, Robert. R. (1994). Fighting by minutes: Time and the art of war. Westport, CT: Praeger.

Leonhard, Robert. R. (1991). The art of maneuver. Novata, CA: Presidio Press.

Lind, William S. (1985). Maneuver warfare handbook. Boulder: Westview Press.

March, J.G. (1996). Exploration and exploitation in organizational learning. In M. D. Cohen & L. S. Sproull (Eds.), Organizational learning (pp. 101-123). Thousand Oaks, CA: Sage Publications.

McIntyre, R.M., & Salas, E. (1995). Measuring and managing for team performance: Lessons from complex environments. In R.A. Guzzo, E. Salas, & Associates (Eds.), Team effectiveness and decision making in organizations (pp. 9-45). San Francisco: Jossey-Bass Publishers.

McKeithen, K.B., Reitman, J.S., Rueter, H.H., & Hirtle, S.C. (1981). Knowledge organization and skill differences in computer programmers. Cognitive Psychology, 13.

Means, B., Salas, E., Crandall, B., & Jacobs, T.O. (1993). Training decision makers for the real world. In G.A. Klein, J. Orasanu, R. Calderwood, & C.E. Zsambok (Eds.), Decision making in action: Models and methods. Norwood, NJ: Ablex Publishing Corporation, 306-326.

Messer, S. B. (1976). Reflection-impulsivity: A review. Psychological Bulletin, 83, 1026-1052.

Metcalfe, J., & Shimamura, A. P. (1994). Metacognition. Cambridge, MA: The MIT Press.

Nelson, Thomas O. (1992). Metacognition: Core Readings. Boston: Allyn and Bacon.

Orasanu, J.M. (1993). Decision making in the cockpit. In E.L. Wiener, R.L. Helmreich, & B.G. Kanki (Eds.), Cockpit resource management (pp. 137-172). NY: Academic Press, Inc.

Patel, V.L., & Groen, G.J. (1991). The general and specific nature of medical expertise: A critical look. In K. A. Ericsson & J. Smith (Eds.), Toward a general theory of expertise: Prospects and limits (pp. 93-125). Cambridge: Cambridge University Press.

Paul, R. W. (1987). Dialogical thinking: Critical thought essential to the acquisition of rational knowledge and passions. In J. B. Baron & R. J. Sternberg, Teaching thinking skills: Theory and practice. New York: W. H. Freeman and Company.

Pennington, N., & Hastie, R. (1993). A theory of explanation-based decision making. In G.A. Klein, J. Orasanu, R. Calderwood, & C. E. Zsambok (Eds.), Decision making in action: Models and methods (pp. 188-201). Norwood, NJ: Ablex.

Ray, M., Y& Myers, R. (1986). Creativity in business. New York: Doubleday.

Scott, W. Richard (1998). Organizations: Rational, natural, and open systems. Upper Saddle River, NJ: Prentice Hall.

Schmitt, J.F. (1994). Mastering Tactics: A tactical decision games workbook. Quantico, VA: Marine Corps Association.

Serfaty, D. (1993). Hypotheses and recent findings on command decision-making expertise. Presentation at U.S. Army Research Institute Workshop on Developing Expertise in Command Decision-Making, Fort Leavenworth, KS, February 4-5.

Shanteau, James. (1992). The Psychology of experts: An alternative view. In G. Wright & F. Bolger (Eds.), Expertise and decision support. New York: Plenum Press. The U.S. Marine Corps (1989). Warfighting. New York: Doubleday.

Shastri, L., & Ajjanagadde, V. (1993). From simple associations to systematic reasoning: A connectionist representation of rules, variables, and dynamic bindings using temporal synchrony. Brain and Behavioral Sciences, 16, 417-494.

Sniezek, J. A., & Henry, R.A. (1990). Revision, weighting, and commitment in consensus group judgment. Organizational Behavior and Human Decision Processes, 45(1), 66-84.

The U.S. Marine Corps (1989). *Warfighting.* New York: Doubleday.

Thompson, B.T., Cohen, M.S., & Shastri, Lokendra (1997). A Hybrid Architecture for Metacognitive Learning (Hybrid Architectures for Complex Learning Program, Office of Naval Research Contract No. N00014-95-C-0182). Arlington, VA: Cognitive Technologies.

Thompson, James D. (1967). Organizations in action. New York: McGraw-Hill.

Toulmin, S. E. (1958). The uses of argument. Cambridge: Cambridge University Press.

Van Creveld, Martin (1985). Command in War. Cambridge: Harvard University Press.

Voss, J.F., Wolfe, C.R., Lawrence, J. A., & Engle, R.A. (1991). From representation to decision: An analysis of problem solving in international relations. In R.J. Sternberg & P.A. Frensch (Eds.), Complex problem solving: Principles and mechanisms (pp. 119-158). Hillsdale, NJ: Lawrence Erlbaum Associates.

Watson, S. R., & Buede, D. N. (1987). Decision Synthesis. New York: Cambridge University Press.

Yukl, G. (1998). Leadership in organizations. Upper Saddle River, NJ: Prentice Hall.

FIGURE CAPTIONS

Figure 1. Three different time orientations differ in where and how they intervene to cause changes in another agent's decision cycle.

Figure 2. Proximity in this space represents degree of correlation among mental models (white boxes), time orientations (white boxes), and two variables (low/high experience and surprise by the enemy). Ovals show high-level structure derived by a hierarchical clustering algorithm. Italicized labels and dotted lines are a suggested two-dimensional interpretation of this space.

Figure 3. Basic components of the Recognition / Metacognition model. Shaded components are meta-recognitional.

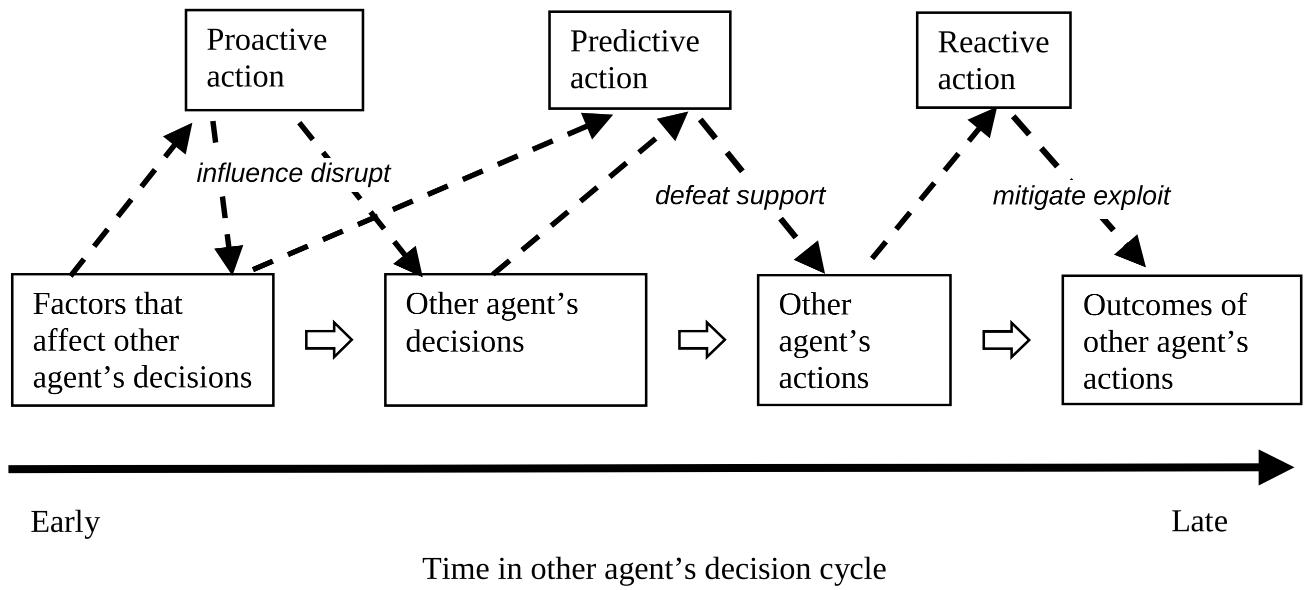
Proactive action
Predictive action
Reactive action
influence disrupt
defeat support
mitigate exploit
Factors that affect other agent's decisions
Other agent's decisions
Other agent's actions
Outcomes of other agent's actions
Early
Late
Time in other agent's decision cycle

Figure 1

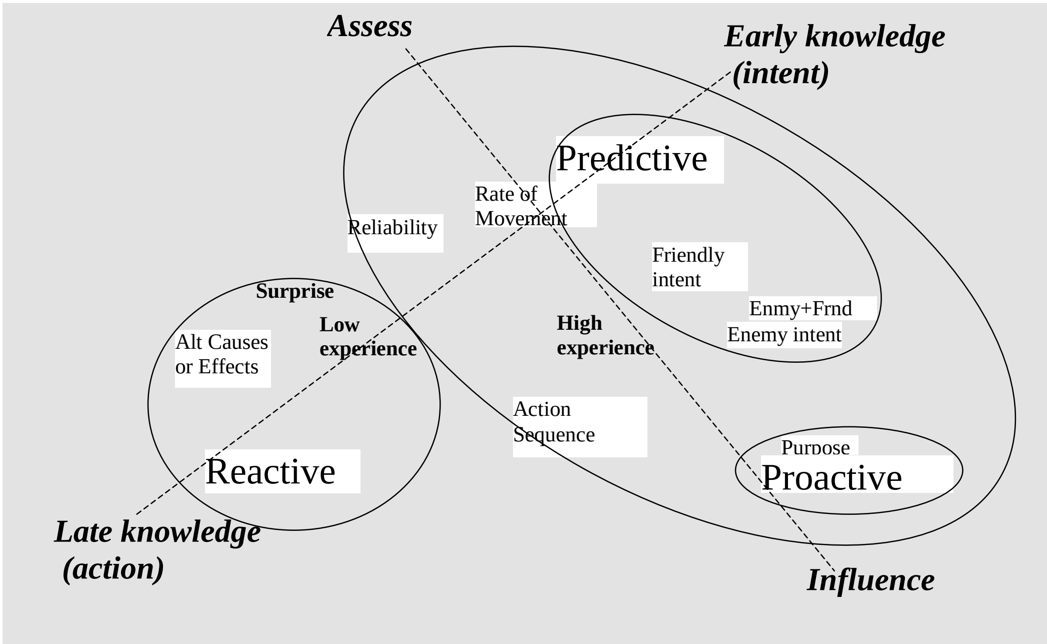
Assess
Early knowledge
(intent)
Predictive
Rate of
Movement
Reliability
Friendly
intent
Surprise
Enmy+Frnd
Enemy intent
Low
experience
High
experience
Alt Causes
or Effects
Action
Sequence
Purpose
Proactive
Reactive
Late knowledge
(action)
Influence

Figure 2

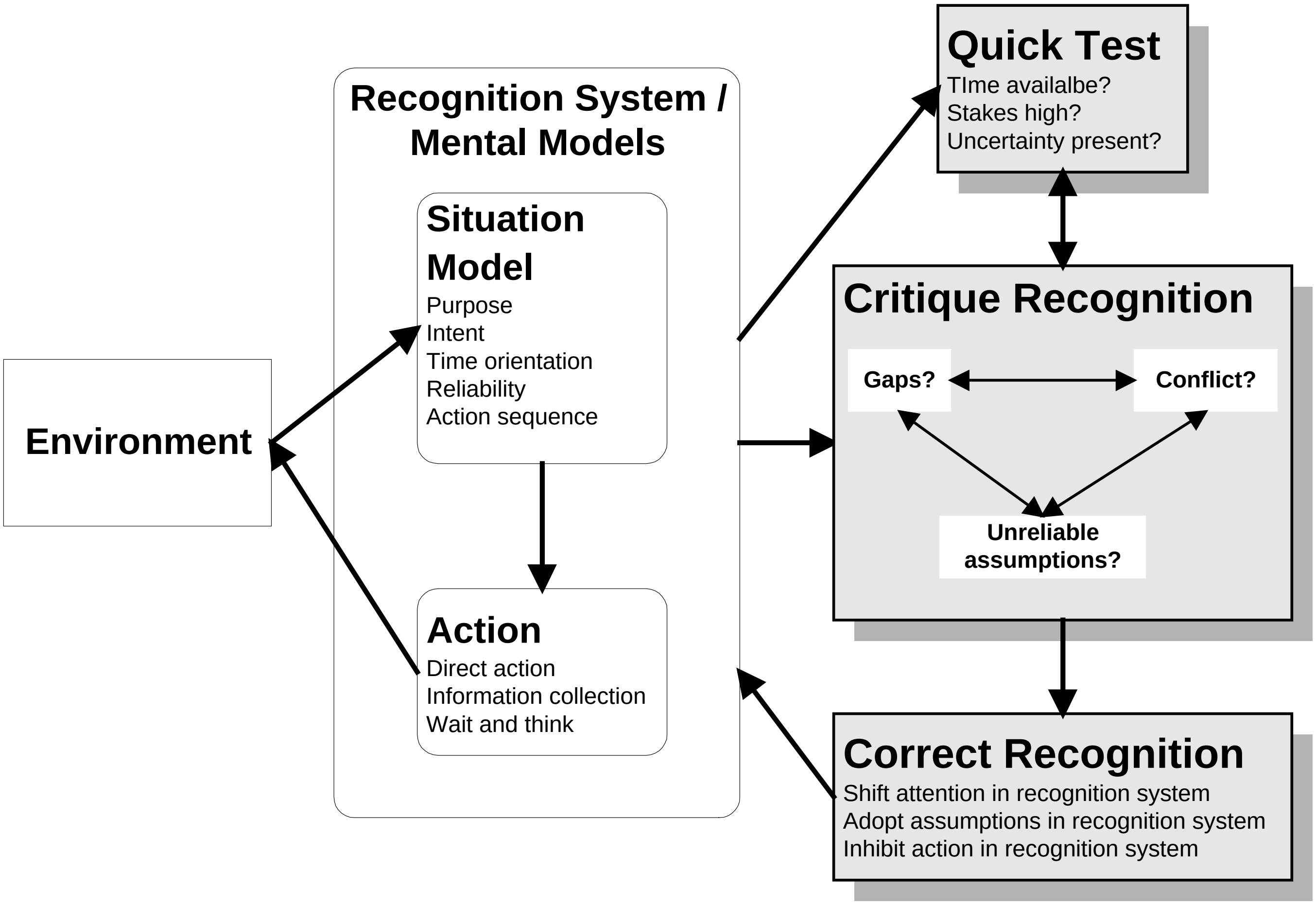
Recognition System / Mental Models
Situation Model
Purpose
Intent
Time orientation
Reliability
Action sequence
Action
Direct action
Information collection
Wait and think
Environment
Quick Test
TIme availalbe?
Stakes high?
Uncertainty present?
Critique Recognition
Gaps?
Conflict?
Unreliable assumptions?
Correct Recognition
Shift attention in recognition system
Adopt assumptions in recognition system
Inhibit action in recognition system

Figure 3