A Comparison of the Decision Ladder and the Recognition-Primed Decision Model

Gavan Lintern
Cognitive Systems Design

Abstract: Cognitive work analysis and cognitive task analysis approach the analysis of decisions in ways that are at least superficially dissimilar. In this paper, I review the two approaches, work (or control) task analysis and naturalistic decision making, to identify similarities and differences, and I assess the implications of looking at decisions from these two different perspectives. I conclude that although these two approaches are superficially dissimilar, they are theoretically compatible. However, the standard form of decision ladder, which is the representational product of work (or control) task analysis, does not take full account of contemporary insights from the three-stage model of situation awareness, the distinction between implicit and explicit cognitive processing, or the principles of naturalistic decision making. I propose modifications of the decision ladder to incorporate these ideas.

Introduction

The recognition-primed decision model has been developed within naturalistic decision-making research, which lies within the more general framework of cognitive task analysis (Militello, Dominguez, Lintern, & Klein, 2010). The decision ladder is the representational product of one particular stage of cognitive work analysis—the stage that deals with activities related to decisions (Vicente, 1999). At first glance, it might seem that the recognition-primed decision model and the decision ladder are covering the same ground. In this paper, I review these two approaches to decision analysis to assess their commonalities and differences. This review reveals that the standard form of the decision ladder, introduced almost 3 decades ago, does not accommodate some significant advances in the understanding of how people make decisions in operational environments. After reviewing the standard form of the decision ladder and the recognition-primed decision model, I propose an updated version of the decision ladder, which I then use as a basis for comparison with the recognition-primed decision model.

Tasks Versus Work

The primary titles of the two overarching frameworks, cognitive task analysis and cognitive work analysis, differ only in the second word, *task* versus *work*, and

ADDRESS CORRESPONDENCE TO: Gavan Lintern, Cognitive Systems Design, 7 Milburn Grove, East St Kilda, Victoria 3183, Australia, glintern@cognitivesystemsdesign.net.

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so it is useful to distinguish these two terms. A task is something to be achieved—in other words, an outcome (Crandall, Klein, & Hoffman, 2006). Work is a constellation of interdependent and interacting responsibilities and activities which is specified in terms of behavior-shaping constraints (Vicente, 1999). Work is a more global construct than is task.

There is some dissension within the discipline of cognitive systems engineering about whether researchers should be analyzing tasks or work but, given the considerable success of each in developing cognitive support products, that dissension seems misplaced. Practitioners of both frameworks analyze tasks; for cognitive task analysis, however, that is the focus of analysis, whereas for cognitive work analysis, tasks are assessed within the context of work.

One potential source of confusion lies in the definition of what constitutes a task. In promoting the framework of cognitive work analysis, Vicente (1999, p. 60) accepted a definition by Kirwan and Ainsworth (1992) whereby a task is "what an operator (or team of operators) is required to do, in terms of actions and/or cognitive processes to achieve a system goal." Vicente concluded that task analysis techniques generally seek to identify the discrete activities or sequences of activities that constitute the ideal or the one best way to perform a job. He argued that this construct is too limiting to capture the realities of modern workplace activities and that instead of analyzing tasks, researchers should be analyzing control tasks, which he defined as goals that need to be achieved, independently of how they are to be achieved or by whom.

However, Crandall et al. (2006) did not think of tasks as discrete activities or as sequences of activities aimed at achieving particular goals but rather as outcomes people are trying to achieve. The definition by Crandall et al., developed within the naturalistic decision-making stream of cognitive task analysis, is not substantively different from Vicente's (1999) definition of control task, and any dissension on this issue is based on a misunderstanding.

Decision Analysis

Following Klein (1998), I take naturalistic decision making to be decision making by experienced people or experienced teams working on operationally realistic tasks in typical work conditions as constrained by high-level, operationally relevant goals. Typical work conditions can be dynamic and can include time pressure, high stakes, inadequate information, ill-defined goals, and poorly defined procedures. Team decisions require coordination among team members. Many of the published decision narratives (Klein, 1989, 1998; Klein & Calderwood, 1991) have described experts responding to sources of subtle perceptual information, which suggests that expertise in naturalistic decision making is based, at least in part, on perceptual learning.

Naturalistic decision making is to be contrasted with rational decision making, in which a decision maker identifies a set of options, identifies ways of evaluating those options, weights each evaluation dimension, rates the options, and finally selects the option with the highest score. Those working in the area of naturalistic decision making do not ignore the possibility that certain decisions will be guided by a rational process, but they typically focus on situations in which time pressures mitigate against the feasibility of rational decision making.

The decision analysis undertaken within the framework of cognitive work analysis is generally referred to as control task analysis, and it features the use of the decision ladder as a representational template. Those working within the framework of cognitive work analysis do not typically focus specifically on naturalistic decisions as they are defined by Klein (1998) but, rather, examine all types of tasks to be undertaken within the operational environment under study.

Decision Analysis Within Cognitive Work Analysis

Control Task Analysis or Work Task Analysis?

Given that there is no substantive difference between a task as defined by Crandall et al. (2006) and a control task as defined Vicente (1999), the use of the word *control* in this context is unnecessary. Furthermore, it is confusing. It suggests a difference when there is none, and the word *control* itself is problematic because it implies a tight, closed-loop, mechanistic regulation, which is precisely the sort of meaning that Vicente was trying to avoid. Although his definition of control is unambiguous, it deviates from the generally accepted meaning of that word. As a practitioner of cognitive work analysis, I prefer the term *work task* to the term *control task,* acknowledging that even the modifier *work* is unnecessary but believing it necessary to use some appropriate modifier here to retain a linguistic connection to mainstream thinking in cognitive work analysis.

Work Task Analysis

Work tasks can be described in terms of the cognitive states established during task execution and the cognitive processes used to effect the transitions between states. These cognitive states and processes are identified by the use of work task analysis, which is one of the stages of cognitive work analysis. The usual product of this stage of cognitive work analysis is a suite of decision ladders.

Work task analysis is based on the assumption that tasks are accomplished, problems resolved, and decisions made via transformations between cognitive states as induced by cognitive processes. A cognitive state is a condition of being (e.g., the state of being alert, the state of being aware of the situation, the state of being certain or uncertain, the state of knowing something), whereas a cognitive process is an activity (e.g., the process of seeking information, the process of planning).

In a physical system, a state is a condition described in terms of phase, form, composition, or structure (e.g., ice is the solid state of H_2O and water is its liquid state). A physical process acts on a state to change it (e.g., the process of cooling transforms water into ice). There can be no state transition in a physical system without an intervening process. Cognitive states and processes can be viewed similarly. In the realm of cognition, processes are often not accessible to conscious awareness, in which case they are said to be implicit.

Knowledge Representation

As the product of work task analysis, a decision ladder (Figure 1) provides a template for mapping "the set of generic sub-tasks involved in decision making" (Rasmussen, Petjersen, & Goodstein, 1994, p. 66)—that is, the cognitive states (depicted as ovals) and cognitive processes (depicted as rectangles). A work narrative can be mapped onto the decision ladder to "represent observed decision paths" and "identify different decision processes" (Rasmussen et al. 1994, p. 66). The decision ladder accommodates both rational and heuristic decision processes. A rational decision process will follow the perimeter of the decision ladder from the lower-left node to the lower-right node, whereas a heuristic decision process can start and finish anywhere in the ladder and can transition via shortcuts across the ladder, three of which are shown in Figure 1. Rasmussen et al. further noted that the decision ladder has three main stages: situation analysis up the left-hand leg, value judgment across the top, and planning and execution down the right-hand leg (see Figure 1).

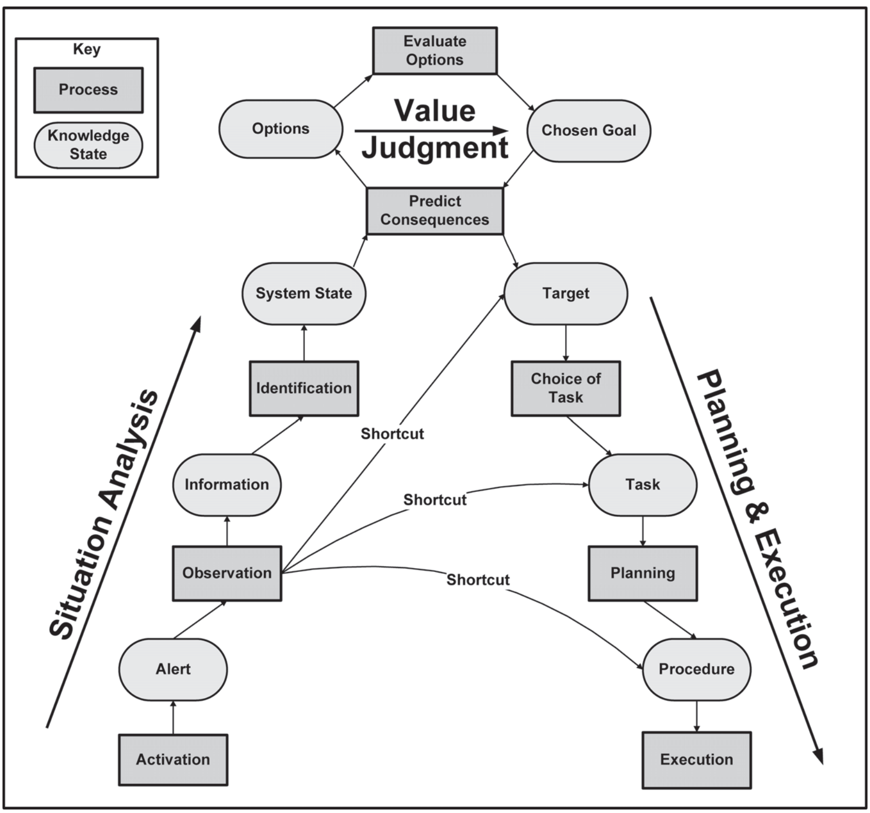

Figure 1. Decision ladder. Cognitive states are depicted as ovals, and cognitive processes are depicted as rectangles. Adapted from Rasmussen (1986) and Rasmussen et al. (1994).

Is the Decision Ladder a Model or a Template?

There is some discussion regarding whether the decision ladder is a model or a template. Some take the decision ladder representation as implying a cognitive decision theory that assumes a fixed, linear sequence of information processing starting from activation; progressing through observation, identification, and the decision processes of options comparison and selection; and finishing with task definition, procedure formulation, and execution. Hollnagel and Woods (2005) took that view when they argued that the decision ladder assumes "an internal representation of a characteristic sequence of actions as a basis for the observed sequences of actions" (p. 63). As evidence for their interpretation, they quoted Rasmussen (1986): "Rational, causal reasoning connects the 'states of knowledge' in the basic sequence" (p. 7).

Whether Rasmussen's (1986) words can be taken as a claim for "an internal representation of a characteristic sequence of actions" (Hollnagel & Woods, 2005, p. 63) is arguable, but that interpretation is at least incompatible with other arguments by Rasmussen (1986) and also with arguments by Vicente (1999), Naikar (2010), and Naikar, Moylan, and Pearce (2006). Rasmussen (1986) has stated explicitly that "the decision ladder is not a model of the decision process itself, but rather a map useful to represent the structure of such a model" (p. 70). Vicente (1999, p. 186) similarly argued that the decision ladder is a template rather than a model. A decision ladder depicts the cognitive states and processes that might be used, rather than those that are used. There is no implication of a fixed sequence of cognitive states and processes for all (or even any) tasks.

It is, however, misleading to suggest that the decision ladder is not a model, at least given the rather loose sense in which the term *model* is used in cognitive engineering. For Rasmussen et al. (1994, p. 65), it shows the "various states of knowledge and information processes required to go from one state to another during reasoning" (p. 65). I take that as an implicit claim that it names all possible cognitive states and processes that might be involved in cognitive work—those classes of cognitive states that are potentially available and those classes of cognitive processes that are needed to transition from one state to another. It does not, however, imply that all of those cognitive states and processes will be involved in any specific exemplar of cognitive work or that there is any specific sequence or constellation of cognitive states and processes that go together. Indeed, the cognitive work analysis literature does not appear to place any constraint on which states can be connected via shortcuts, which suggests a theoretical claim that any cognitive state can be reached from any other cognitive state via an appropriate cognitive process.

Shortcuts or State Transitions?

The use of the term *shortcut* to refer to transition links that do not follow the rational decision path around the perimeter of the decision ladder is possibly an unfortunate characterization because it implies precedence for transitions that do follow the perimeter. Preferably, one could dispense with that term and talk only of state transitions, thereby avoiding any implication of a preferred sequence of cognitive states and processes.

Decision Ladders as Narrative

As I note previously, the decision ladder should not be interpreted as implying a fixed sequence of cognitive states and processes for all, or even for any, tasks. Nevertheless, it should be possible to first map a work narrative onto a decision ladder and then to read that decision ladder.

A work narrative that follows the perimeter of the decision ladder, starting at the lower-left node and finishing at the lower-right node, might be read as follows:

> A worker may detect a need for action. On being alerted, he or she will seek to discover what is going on by observing the situation, taking note of information about the task and about the surrounding conditions. With that set of observations in hand, the worker will seek to understand what lies behind the observations by identifying the present state of the system. On becoming aware of the system state, the worker will evaluate the consequences of the present state of the system for the current task and will subsequently identify a target state.
>
> Alternatively, it may be difficult to identify a satisfactory target state directly from an understanding of the present system state, in which case the worker will divert through the value-judgment loop to identify and then evaluate the options in order to settle on an ultimate goal. He or she will then evaluate the consequences of the chosen goal for the current task in terms of relevant criteria and will subsequently identify a target state that will satisfy those criteria.
>
> Once the target state is identified, there will be a need to choose a task that will achieve that state. The worker will then plan a procedure for executing the task and, finally, will execute the procedure.

Other workers at different levels of experience may follow other trajectories, and the same worker may opportunistically follow different trajectories at different times for the same task. An expert is likely to visit far fewer cognitive states and to employ far fewer cognitive processes than a novice but may also choose different trajectories at different times. That is not to say that anything is possible; the chosen trajectory must in some way reflect the needs of the work task. Why workers, either novice or expert, might choose a different trajectory at a different time will often be an interesting issue to explore, one that might have ramifications for the design of a cognitive support tool.

Knowledge Elicitation

Texts and papers on decision analysis undertaken within the framework of cognitive work analysis are generally silent on knowledge elicitation methods. Typically, the methods used are consistent with recommendations to be found within standard texts on cognitive task analysis (e.g., Seamster, Redding, & Kaempf, 1997).

Design Implications

Enhanced cognitive support might come through one of, or some combination of, technological redesign, work process redesign, or training focused on the specific cognitive states or processes that offer a challenge in the execution of work tasks. Every cognitive state and every cognitive process involved in the execution of a work task is a candidate for assistance with some form of technological, process, or training support. Whether any form of technological support is desirable for any specific cognitive state or process will depend largely on whether that state or process offers a particular cognitive challenge that could be eased by the form of intervention being proposed.

Decision Analysis Within Naturalistic Decision Making

Recognition-Primed Decisions

The research on naturalistic decision making has led to the recognition-primed decision model (Figure 2; Klein, 1998). As its name implies, decisions flow from recognition. One or more critical elements of a situation are recognized as being similar to something experienced previously, and that recognition encourages development of a course of action similar to one that had been effective on that previous occasion. Recognition-primed decisions are common in complex, time-constrained domains in which decision makers have a high level of expertise, ranging from 42% of all decisions for tank platoon leaders up to 95% for naval Aegis commanders (Klein, 1998, p. 97).

Figure 2 depicts a number of variations in recognition-primed decisions. A decision maker will commonly select a course of action based on situational recognition and then execute it without further consideration or, alternatively, may mentally simulate the effectiveness of the course of action prior to execution. Following that assessment, he or she may accept, reject, or modify the selected course of action. If the decision maker rejects the course of action, he or she may select another typical action based on the original recognition of typicality or may reassess that original judgment of typicality before selecting another typical action. After recognizing typicality, the decision maker

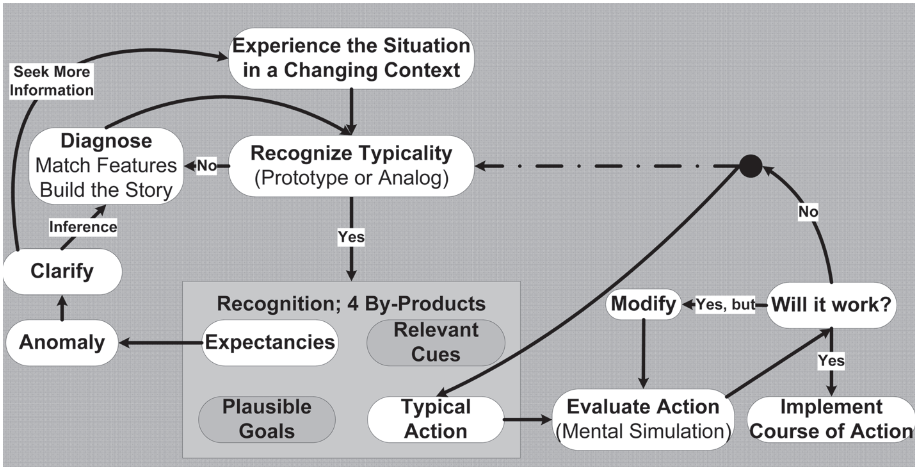

Figure 2. The recognition-primed decision model. From Sources of Power: How People Make Decisions *(p. 27) by G. Klein, 1998, Cambridge, MA: MIT Press. Copyright 1998 by MIT Press. Adapted with permission.*

might also become aware of an anomaly (in which the situation is not quite as typical as it first appears) and may attempt to clarify either by seeking more situational information or by diagnosing the situation through feature matching or story building.

Recognition-Primed Narrative

As illustrated by the following example abbreviated from Klein (1998), the recognition-primed decision model has been developed from analysis of expert decision or task narratives:

> The commander of an emergency rescue team was called to the assistance of a woman who had fallen or jumped from a highway overpass. Instead of plunging to her death, she had hit the metal struts supporting some signs, and was dangling on these when the team arrived. The commander recognizes the danger of the situation (*experience the situation in a changing context*). The question is how to pull woman to safety (*recognize typicality*). The commander considered using a Kingsley Harness that would snap onto her shoulders and thighs (*typical action*) but, as he imagined carrying out such a rescue (*evaluate action*), he realized that it would be dangerous to attach the harness to a semiconscious woman lying on her stomach. She would have to be lifted to a sitting position, held still, and so on, while keeping everyone balanced on the narrow support poles (*will it work?*). So he rejected this option (*No, it will not work*). . . . Then he realized he could use a ladder harness for the rescue (*recognize typicality*). The woman would just have to be lifted up an inch or two, the harness slid under her, the buckle attached, and a rope tied to a clasp on the harness to lift her to safety (*modify typical action*). The commander imagined this scenario a few times (*evaluate action*) and ordered his crew to use a ladder harness to make the rescue (*implement course of action*). (p. 18)

Knowledge Elicitation

Knowledge elicitation for recognition-primed decisions uses the critical decision method, which elicits information within a specific challenging incident about cognitive functions such as decision making, planning, and sense making. An operational expert is asked to describe decisions he or she made during an incident and also to describe the information and rules of thumb he or she used during the decision process. The expert is further asked to identify situational features that might have made decisions difficult and situational elements that characterized the incident as familiar. The interviewing team (usually two: an interviewer and a recorder) works through four sequential sweeps:

- Incident identification captures the basic elements of a particularly challenging incident as described by an operational expert.
- Time-line verification establishes the sequence of events, identifies inconsistencies and the time and duration of the incident, and assembles the events into chronological order.

- Deepening employs cognitive probes to explore decision points and changes in situation awareness.
- Error identification employs "what if" probes to examine hypothetical errors, errors committed by the expert, or errors that might be committed by workers with less experience.

Information from the first and second sweeps is used to identify decision points and to select decisions for further analysis in the third and fourth sweeps. It is the information from these third and fourth sweeps that constitutes the substantive output of the critical decision method.

Knowledge Representation

Information from the third and fourth sweeps is generally entered into a decision requirements table, as shown in Table 1. The format of the decision requirements table is not fixed; the number of columns and column titles vary between research projects. A noteworthy feature of Table 1 is the explicit inclusion of design solutions (column 3) for the various problems identified (column 2) for each of the decisions and cognitive requirements examined in the analysis (column 1). This explicit naming of potential design solutions is relatively unusual in cognitive systems engineering and is not even a universal feature of decision requirements tables that summarize the results of analyses based on the critical decision method (e.g., see Crandall et al., 2006).

Design Implications

As with work task analysis, enhanced cognitive support might come through one or some combination of technological redesign, work process redesign, or training focused on the decision or cognitive requirements identified in the analysis. The

TABLE 1. Decision Requirements Table for an Airborne Warning and Control System Weapons Director

Decision and Cognitive Requirements	Difficulty	Human Computer Interface Solution
Anchor sense making around key threats and assets	Screen clutter Important tracks not identified Dynamics of situation become complex Loss of understanding	Symbology for flagging threats and key assets (e.g., tankers)
Maintain situational understanding	Screen clutter Operators must look away from scope to input actions Cannot differentiate geographical boundaries Communication workload	On-screen menu Symbology Boundary differentiation

From *Working minds: A practitioner's guide to cognitive task analysis*. (p. 175) by Beth Crandall, Gary Klein, and Robert R. Hoffman, published by The MIT Press.

implication of this model for time-stressed, critical decisions at least is that rather than being concerned with computational cognitive processes, one should identify the information that guides decisions, the sort of experience that builds expertise, and the mental models that help people evaluate whether a planned course of action will be effective. As suggested by Table 1, design solutions can be motivated by cognitive challenges listed in a difficulty column. The process of moving from a cognitive challenge to a design solution is not made explicit in the literature, but diverse solutions are identified for different cognitive challenges (e.g., Crandall et al., 2006; Kaempf, Klein, Thordsen, & Wolf, 1996; Klein, 1998). Specific solutions are presumably proposed on the basis of a creative inference stimulated by the particular design challenge.

Reassessment of Decision Analysis Within Cognitive Work Analysis

There has been considerable progress in how decision processes are understood since Rasmussen (1986) developed the decision ladder more than 20 years ago, but the decision ladder has remained unchanged. In this section, I propose an update of the decision ladder to take account of this progress. Relevant insights can be drawn from the literature on situation awareness, on naturalistic decision making, and on implicit knowledge. Additionally, several terminological and formatting issues make the decision ladder difficult to understand, and I use this section to resolve those issues. The updated decision ladder is shown in Figure 3. The discussion within this section should not be taken as a radical reinterpretation of the standard decision ladder but, rather, as a refinement that aligns it more closely to current knowledge about decision making.

Situation Awareness

The left-hand leg of the decision ladder takes account of situation analysis, which might also be understood as situation awareness. The best developed contemporary account of situation awareness is from Endsley (1995). She posited three levels of situation awareness: perception of the current situation, understanding of the current situation, and anticipation of how the situation will evolve. Note that the term *situation awareness* refers not only to awareness about task status but also awareness about contextual details that might influence decisions if something unexpected happens. Whereas this latter aspect of situation awareness would seem to be implied in the recognition-primed decision model node called "experience the situation in a changing context" in Figure 2, the emphasis within treatments of the decision ladder has been on task status. In this update of the decision ladder, I propose an adjustment to take account of this concern.

The standard decision ladder (Figure 1) places the first of Endsley's (1995) levels in the bottom two state nodes of the left-hand leg, "alert" and "information," and places the second level in the third node, "system state." Although the standard decision ladder has a process for predicting the consequences of the current situation, the state node to which that process leads is the "target" or desired state of the system and is in the planning leg. To be consistent with contemporary theory on situation awareness, the anticipated state should be in the situation analysis leg, and it should not be confounded with the target state.

To correct this problem, the updated decision ladder (Figure 3) collapses the two bottom-left state nodes to result in a state description of being "alerted to the dimensions of the situation," as is consistent with the first level of situation awareness theory. The second node provides a state description of being "aware of the

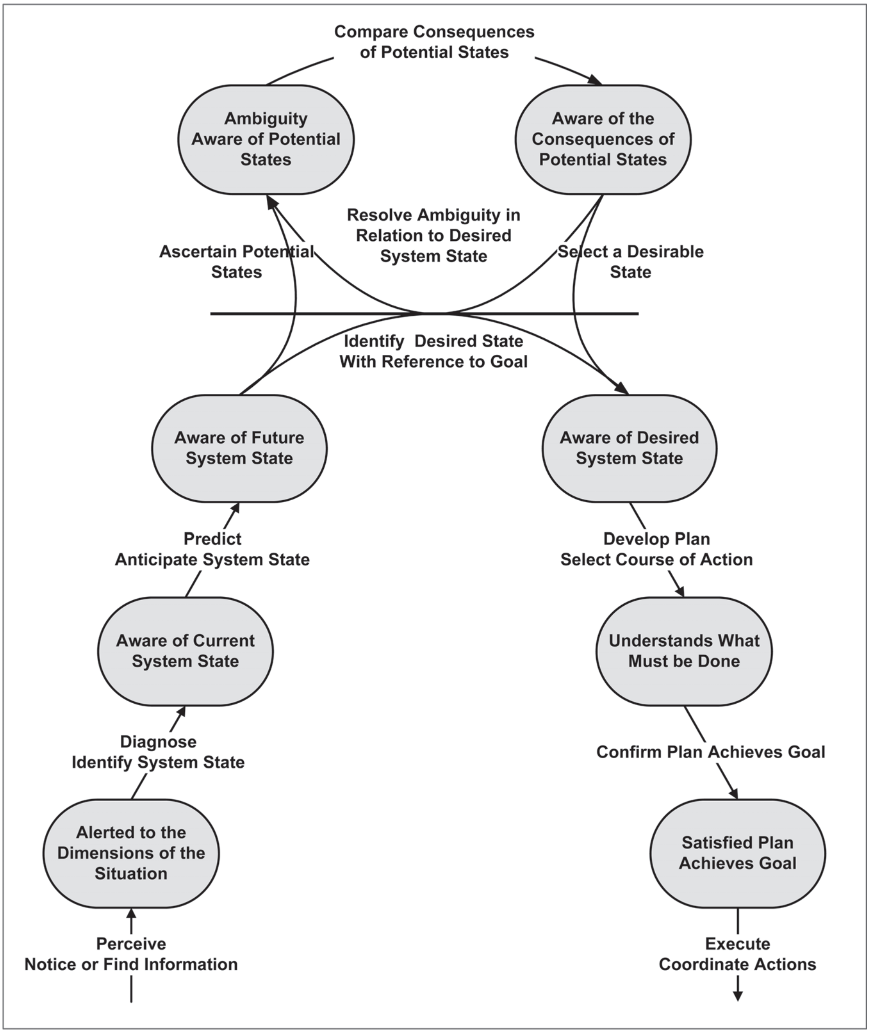

Figure 3. Updated decision ladder.

current system state" and the third node of being "aware of the future system state," as consistent with the second and third levels of situation awareness theory. Both task status and contextual details contribute to these three cognitive states.

Naturalistic Decision Making

One of the more insightful aspects of the recognition-primed decision model is the incorporation of an action evaluation function. The standard decision ladder associates an evaluation function with rational comparison of options, but the naturalistic decision research reveals that evaluation, undertaken independently of any rational decision process, is embedded in the planning and execution processes.

This is accommodated within the updated decision ladder by collapsing the two states that identify the "task" and the "procedure" (Figure 1) for executing the task into a state of "understands what must be done" (Figure 3) to achieve the desired system state. The bottom right state in the updated decision ladder is now identified as that of being "satisfied" that the "plan achieves [the] goal."

The process that transforms the state of understanding of what must be done into one of being satisfied that the plan achieves the goal is identified as "confirm plan achieves goal."

Implicit Processes

State transitions (identified as shortcuts in discussions of the standard decision ladder) come in two forms, those being *shunts* and *leaps*. A *shunt* is an explicit or conscious process that transforms one cognitive state into another. A *leap* describes a direct association between two cognitive states and carries an implication of a state transition with no intervening process. That is a disconcerting implication because, in the physical world at least, state transitions require an intervening process. Preferably, the type of cognitive event that appears to be process free might be characterized as one in which the process is implicit. That strategy would align this part of the theoretical argument underlying the decision ladder with an extensive body of research and theory on human expertise that distinguishes implicit from explicit knowledge.

Readability

The state and process labels in the standard decision ladder are succinct in the extreme and can be difficult to interpret. The descriptions in the updated decision ladder clarify what is meant at different points in the template. There is a fine line between being too succinct and too verbose, but some expansion of the original descriptions seems warranted.

Some of the identifiers in the standard decision ladder are misleading. For example, a state node toward the upper left of the standard form (Figure 1) is designated as "system state." By a literal reading, a system state is a physical state, but the states mapped onto the decision ladder template are cognitive states. However, this particular node represents the cognitive awareness of the system state and is therefore fully consistent with the intent, but those who read decision ladders for the first time can miss that distinction. Furthermore, the distinction between state and process is not clearly drawn by the identifiers. Processes should be identified by verbs, but

Rasmussen et al. (1994) used noun forms to identify most of the process names (e.g., "activation"). These sorts of ambiguities are eliminated in the updated decision ladder.

The standard decision ladder codes a state as an ellipse (or a circle) and a process as a rectangle. Beginners have considerable trouble keeping this straight because, I suspect, a box implies stasis. In contrast, an arrow implies action and so the updated decision ladder codes processes as arrows.

A Narrative for the Updated Decision Ladder

A work narrative that follows the perimeter of the updated decision ladder, starting at the lower-left node and finishing at the lower-right node, might be read as follows:

> A worker who is immersed in a work situation will be aware of the types of events that demand intervention. On becoming alerted to or aware of such an event, he or she will engage in situation analysis to discover what is going on. He or she will first seek information about the task and about the surrounding conditions and, with that information in hand, will seek to identify the current system state and to anticipate the future system state given no intervention while remaining cognizant of situational exigencies that may demand reassessment. The worker will then identify a desirable and reachable system state.
>
> Alternatively, it may be difficult to identify a desired system state directly from the situation analysis, in which case the worker will divert through the value-judgment loop to identify and then evaluate the potential states in order to compare the consequences of those potential states as a prelude to settling on a desirable system state.
>
> Once a desirable system state is identified there will be a need to develop a plan or select a course of action. Once that is done, the worker will confirm that the plan achieves the goal. If satisfied, the worker will execute the plan.

Design Implications

As noted in the discussion of design implications for the standard decision ladder, every cognitive state and every cognitive process involved in execution of a work task is a candidate for assistance with some form of technological, process, or training support. Figure 4 suggests some possibilities for the updated decision ladder.

Model Comparison

Neither the decision ladder nor the recognition-primed decision model is as aptly named as one might wish. Both deal with more than decisions. For example, situation analysis is an important feature of each. In some work tasks, decision making is not the most substantive activity. Kaempf et al. (1996) reported that naval Aegis commanders are more concerned with developing situation awareness than with determining which actions to take. However, the current names for

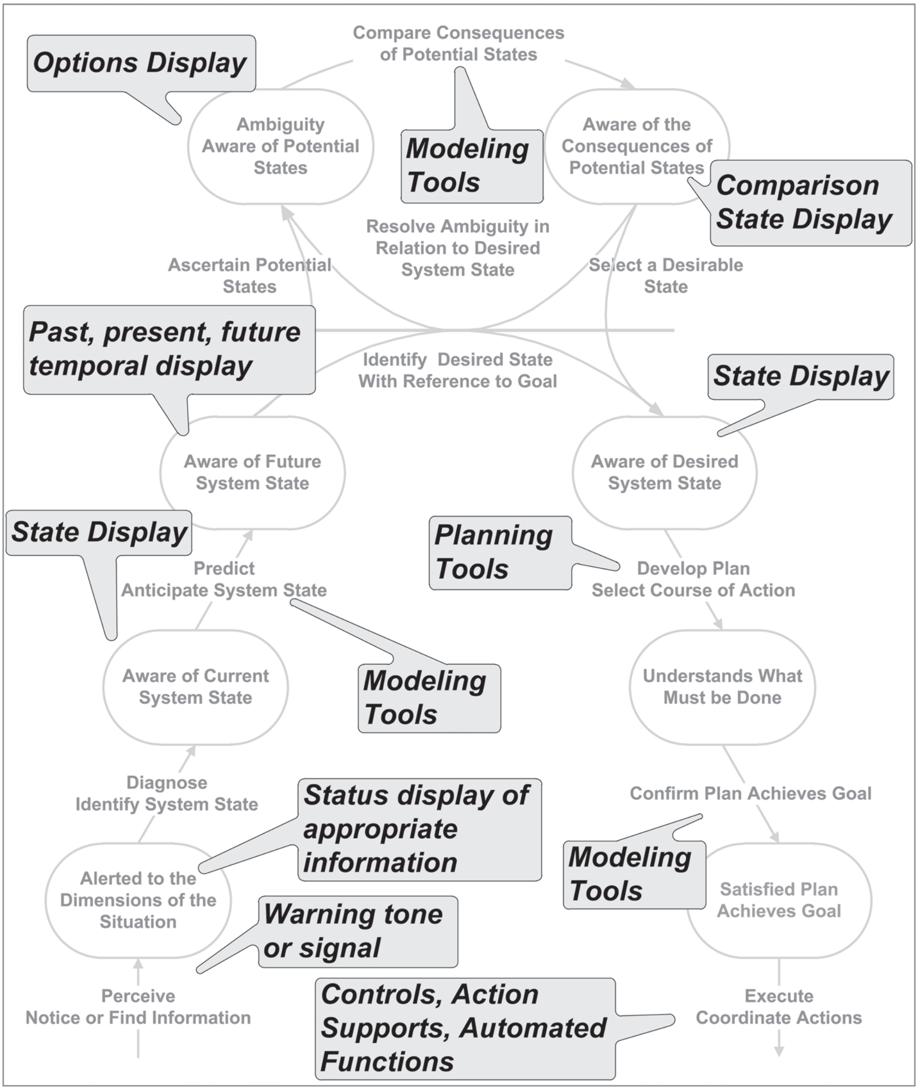

Figure 4. A sample of potential design interventions.

these two models are so widely accepted that any change at this time would generate confusion and dissension, although it should be recognized that each goes beyond the specifics of decision making.

Product Versus Process Description

The recognition-primed decision model is largely an account of how a work task is done. There is, however, some uncertainty about the status of the decision ladder in this regard. Vicente (1999, p. 187) claimed that the decision ladder "is used to develop a product description rather than a process description," the goal at this stage of analysis being "to find out what needs to be done, not how it can be done" (p. 187) It is not entirely clear what Vicente intended by the product versus process description claim. Clearly, the decision ladder names something to be achieved, a work task, and that can reasonably be characterized as a product. However, Vicente (1999, p. 193) also observed that the decision ladder incorporates "two kinds of constructs," those being "information processing activities" and "states of knowledge" (p. 193). In these terms, the decision ladder is a state-activity description more closely allied with a process description of how something is done rather than a product description.

History

At least some of the differences between these two models are stimulated by the differences in focus during early developments. The framework of cognitive work analysis emerged from the work of Rasmussen (1986), who was concerned with human reliability within nuclear power generation, whereas the recognition-primed decision model emerged from the naturalistic decision-making research of Klein (1989). These are two quite different problems. The analysis of human reliability within a large-scale, sociotechnical system such as nuclear power generation demands a comprehensive systems approach, whereas the analysis of decisions within critical, time-constrained situations demands a focused, investigatory approach. As a result, the framework surrounding the decision ladder is structurally more suited to analysis and design of extended systems and the framework surrounding the recognition-primed decision model is structurally more suited to the design of cognitive support systems for individuals and teams.

The respective concerns with systems design versus design of cognitive support have almost certainly contributed to the different developmental trajectories. Rasmussen's (1986) early development of cognitive work analysis produced a framework that is very close to what is used today. Those who have followed his lead have contributed a great deal by reorganizing stages of cognitive work analysis and developing more consistent descriptions of the framework, but there have been no substantive changes to the framework itself. In contrast, Klein's (1989) early research on naturalistic decision making and his refinement of the critical decision method has evolved into the framework now known as decision-centered design (Militello et al., 2010). Other elements of this latter framework, such as macrocognition, team cognition, and decision-centered design itself, have evolved as the approach has matured.

Analytic Goals

Cognitive work analysis was developed as a means of resolving what is now known as the task-artifact cycle (Carroll & Rosson, 1991) or the envisioned-world problem (Woods & Hollnagel, 2006). The term *task-artifact cycle* refers to the coevolution of tasks and artifacts. Technical solutions are developed for problems experienced in the execution of tasks, but those technical solutions then constrain the way tasks are executed. Thus constrained, the new form of practice will often fail to take full advantage of new opportunities, which will possibly prompt a redesign effort. The envisioned-world problem is related; "since the introduction of new technology will transform the nature of practice" (Woods & Hollnagel, 2006, p. 58), how can one envision and subsequently design a new form of work practice that is not detrimentally constrained by current practice.

New technology will inevitably transform work practice. One goal of cognitive systems engineering is to direct that transformation explicitly to ensure that new work practices will be effective and robust in contrast to them emerging spontaneously and thereby possibly being fragile and cognitively intensive. Carroll and Rosson (1991) and Woods and Hollnagel (2006) offered ideas about how to deal with this issue, both arguing for an approach that uses insights from current practice to develop generic patterns or prototypical principles for the design of future practice. Although the task-artifact cycle and the envisioned-world problem are not typically discussed in the literature on decision-centered design, the design strategies it employs rely similarly on use of generic patterns or prototypical principles abstracted from current practice.

Cognitive work analysis employs this approach in part, but it also seeks explicitly to break the coevolutionary link between current and future work structures by mapping the structural constraints of the envisioned work domain as a foundation for the design of a new form of work practice not constrained by current technology or by current work practice. Work domain analysis and its representational product, the abstraction-decomposition space, are central to this strategy, and work task analysis is guided by its results (Lintern, 2009b). This strategy of mapping the structural work constraints is unique within cognitive systems engineering and adds a potent tool for addressing the envisioned world problem.

Analytic Content

The recognition-primed decision model (Figure 2) is quite different in appearance from the decision ladder (Figures 1 and 3) but is similar at a conceptual level. Some of its nodes (e.g., experience the situation in a changing context, recognize typicality, evaluate action, implement course of action) are cognitive processes, whereas others (the four by-products of recognition) are cognitive states. However, the cognitive states and processes are not as clearly distinguished as they are in the decision ladder, possibly because the model is linked more closely in the literature to the theory of macrocognition, which emphasizes "the collection of cognitive processes and functions that characterize how people think in natural settings" (Crandall et al., 2006, p. 136), functions such as planning and naturalistic decision making and their supporting processes such as problem detection and attention management. Klein (1998) noted a concern with "how one state of knowledge [is] transformed into another and the situation awareness at each stage" (p. 190), but this notion of state transformation is not well developed in the naturalistic decision-making literature.

One notable but conceptually superficial difference is that the decision ladder is used as a template of all possible cognitive states and processes, even those that are not active within a specific narrative, but the representation of the recognition-primed decision model is often adapted to the specific narrative (e.g., Klein, 1998). Elements are removed or added to the representation as needed, although, in common with the decision ladder, there is a relatively small number of potential elements.

Although there is little overlap between the two models in terms of specific words used to describe states and processes, there is conceptual correspondence between the two models on many elements. Table 2, which maps the process correspondences between the two models, suggests that the decision ladder is more comprehensive but also suggests that the process descriptions at least are similar. The recognition-primed decision model is less systematic than the decision ladder regarding the naming of states, and so there is little contact between the models in relation to state descriptions.

Looping processes are possible in both models. The recognition-primed decision model shows explicit loops for seeking more information, clarifying anomalies, and modifying or changing plans after identifying an anomaly or after assessing whether a selected course of action will work. The decision ladder accommodates loops by the insertion of new process links, although any such link should be similar to one already named in the basic template.

As is consistent with the overarching frameworks guiding these two models, cognitive work analysis versus decision-centered design, the decision ladder offers a structure for guiding consideration of all potential cognitive states and processes, whereas the recognition-primed decision model focuses on key features of expert decision making that could potentially identify points of leverage for design. The recognition-primed decision model makes no reference to option comparison or selection but, as noted in Table 2, the recognition-primed decision literature does not exclude the possibility of a rational options-comparison method for decision making.

Given its significance within decision-centered design, one might question how macrocognition relates to work task analysis. I suggest that macrocognitive functions such as planning and naturalistic decision making have the status of work

TABLE 2. Process Correspondences Between the Decision Ladder and the Recognition-Primed Decision

Decision Ladder	Recognition-Primed Model
Notice or find information	Experience the situation in a changing context
Diagnose	Diagnose (match features, build story, recognize typicality)
Predict	Expectancy
Identify desired state	Typical action
Develop plan	*Discussed but not in the model*
Confirm plan achieves goal	Evaluate action (mental simulation)
Coordinate and execute actions	Implement course of action
Ascertain potential states	*Discussed but not in the model*
Compare consequences of potential	*Discussed but not in the model*
Resolve ambiguity in relation to desired system state	*Discussed but not in the model*

tasks, whereas supporting processes such as problem detection and attention management have the status of cognitive processes (e.g., problem detection is likely to align with diagnosis in the decision ladder, whereas attention management is likely to align with perception).

Elicitation and Representation of Knowledge

These two frameworks differ in their treatment of knowledge elicitation. The critical decision method has a history in behavioral science, and the naturalistic decision-making research has performed a service in resurrecting and refining this potent knowledge elicitation method. Treatments of cognitive work analysis are typically silent on knowledge elicitation methods, and many of its practitioners presumably do not adhere to the principle, essential to data collection with the critical decision method, of having subject matter experts narrate actual noteworthy events.

On the other hand, in his initial development of the framework of cognitive work analysis, Rasmussen (1986) made some unique contributions in relation to the representation of knowledge. The decision ladder and also the abstraction-decomposition space are original and, at least for those who can read them, powerfully evocative. The decision requirements table, although useful, could not be classified as an original contribution to representational forms. In contrast to the decision ladder, it is an atheoretical form and does not therefore benefit or suffer from the constraints of a theoretical framework.

Reprise: How Different Are the Models?

Table 2 reveals a conceptual similarity between the two models. Even the constructs found in the decision ladder but not in the recognition-primed decision model are acknowledged elsewhere in the naturalistic literature. Naikar (2010) has, in contrast, concluded that these two models are significantly different. Our difference in opinion evolves at least partially from our different goals. Naikar (2010) has contrasted these two models at the level at which they are described in the literature and, as I noted previously, there are noteworthy differences. In contrast, I have sought to see behind the descriptions to tease out the fundamental structures. From that perspective, I see no substantive differences.

Naikar (2010) posed the following distinction. She argued that the decision ladder is concerned with representing what must be done in a work domain independently of how it is done or by whom, whereas the recognition-primed decision model does not distinguish between these aspects. Specific to the decision ladder, this claim echoes one made Vicente (1999). I take this claim as a caution against committing to a particular human or technological solution too early in the analytic process—for example, a caution against assuming that the proposed design must have the human operator doing everything even if that is the case in the current system. This is allied to the task-artifact cycle and envisioned-world problems I discussed previosly. Naikar's claim would seem to imply that those subscribing to the recognition-primed decision model are prone to making this sort of mistake. I find considerable evidence to the contrary in Klein (1998) and in Crandall et al. (2006).

Naikar (2010) further argued that the recognition-primed decision model focuses on expert decision-making in familiar situations, whereas the decision ladder is concerned with the various behaviors that can occur under different conditions—for instance, when experts are confronted with unfamiliar situations or when novices are engaged in performing certain tasks. Although it is true that one common decision process as described by the recognition-primed decision model (selection of a course of action based on situational recognition, followed by execution without further consideration) focuses on familiar, immediately recognizable situations, other variations as I described earlier in this paper and as described by Klein (1998) address decision processes in which the situation is not immediately familiar or the common response to the situation may not work.

Additionally, those subscribing to the recognition-primed decision model would likely argue that any situation confronted by an expert has both familiar and unfamiliar components and that experts leverage the familiar to cope with the unfamiliar. Even within the framework of cognitive work analysis, in which an explicit and systematic effort is made to design systems that help people cope with the unfamiliar, cognitive engineers are building on this principle of using the familiar as a basis for adapting to the unfamiliar.

Naikar (2010) also pointed out that the recognition-primed decision model focuses primarily on expert decision making. Although this is substantially accurate, I see nothing in the recognition-primed decision model that prevents its application to the study of novice behavior. I regard this preference for studying expertise as a pragmatic choice rather than as a constraint imposed by the model.

Overall, although I find Naikar's (2010) arguments informative, I remain unpersuaded that there are substantive differences between the models.

Task Trajectories

If the two models are as similar as I suggest, it should be possible to map the same work task narratives onto both. In that my own relevant experience is primarily in the use of decision ladders, I will demonstrate this practical compatibility by mapping recognition-primed activities onto decision ladders (Figure 5).

Figure 5a shows two possible trajectories for braking an automobile in response to the brake lights of an automobile in front. This may be a fully implicit response, in which the driver is not even aware of noticing the brake lights, or one in which the driver notices them consciously and then immediately executes a braking response.

Figure 5b maps a recognition-primed event described by Kaempf et al. (1996) in which an expert experiences the situation in a changing context, recognizes its typicality, selects a typical course of action, and then implements that course of action without further consideration.

Figure 5c maps a recognition-primed sequence described by Klein (1989) in which a fire commander experiences the situation in a changing context but then seeks more information before implementing a course of action.

Figure 5d maps a recognition-primed narrative from Klein and Calderwood (1991) in which an emergency rescue commander experiences the situation in

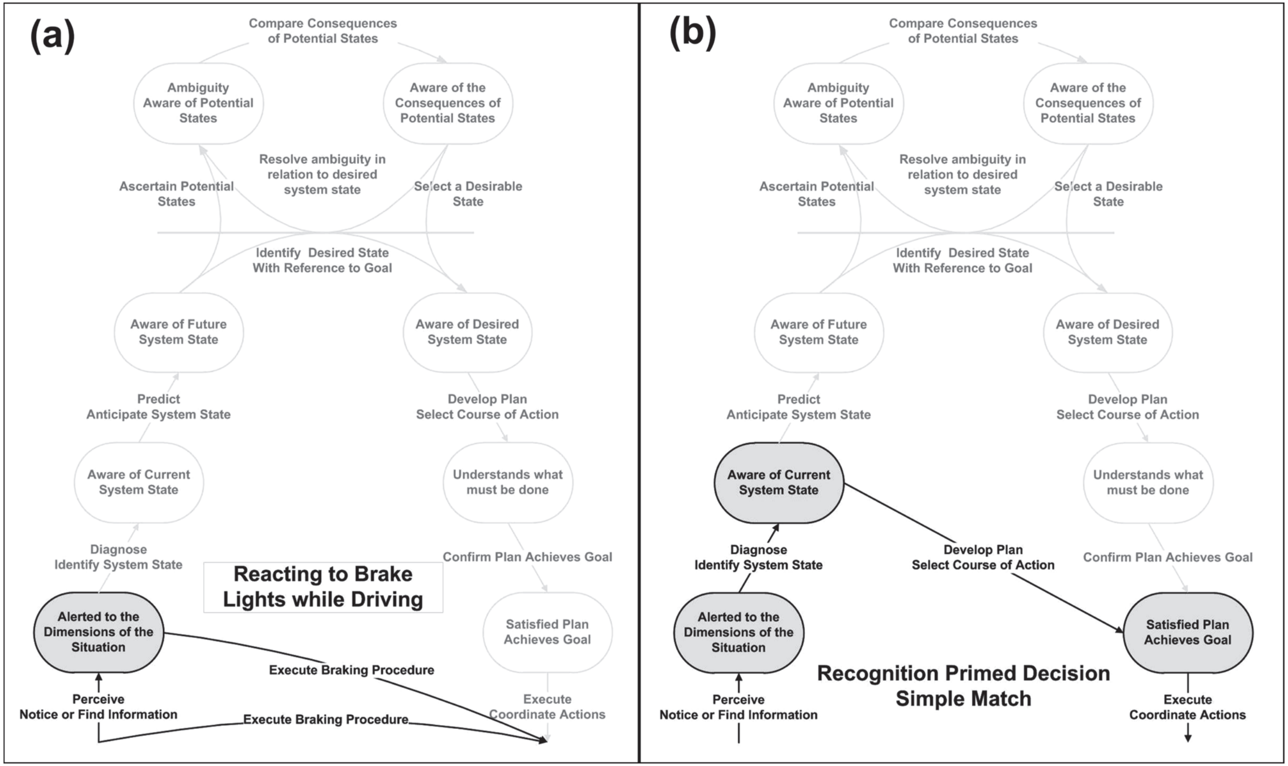

Figure 5. Decision ladders for a variety of recognition-primed tasks. (a) Two possible trajectories for braking an automobile in response to the brake lights of an automobile in front. (b) A recognition-primed event in which a typical course of action is implemented without further considerations. (Continued on page 324.)

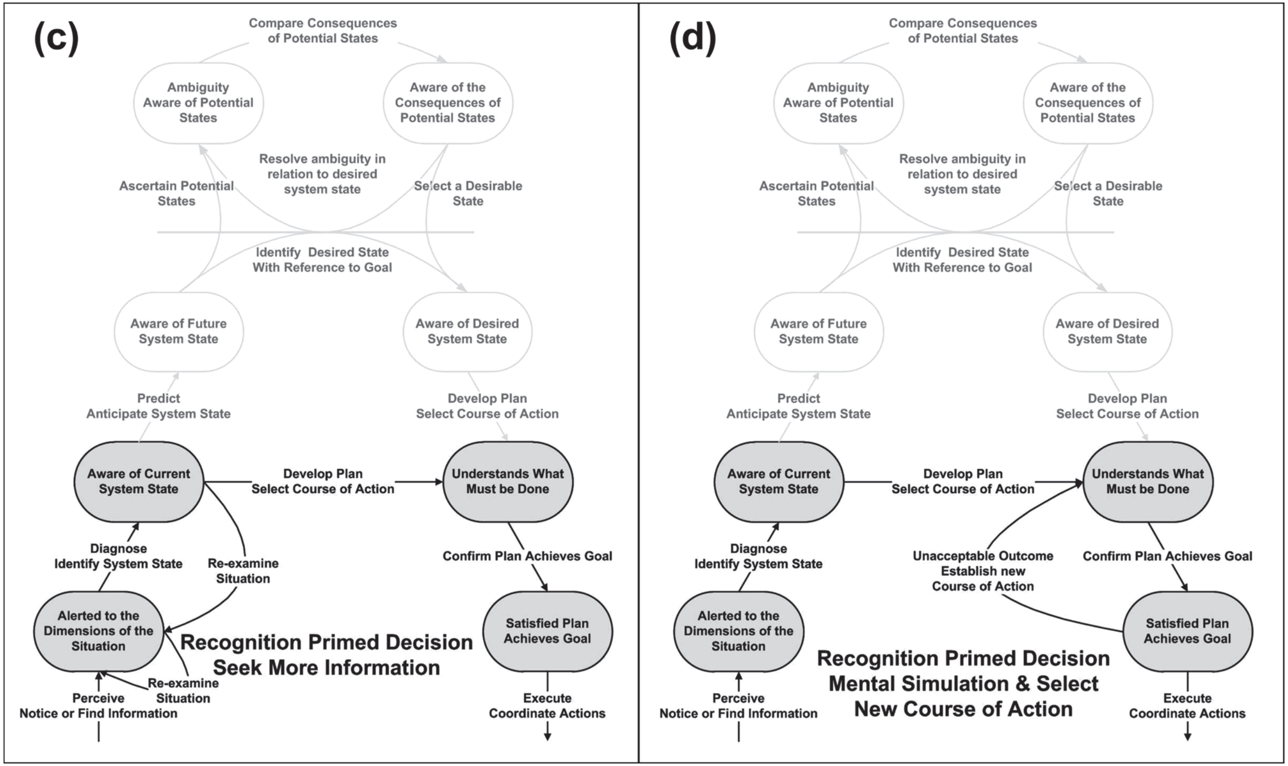

Figure 5 (continued from page 323). Decision ladders for a variety of recognition-primed tasks. (c) A recognition-primed sequence in which more information is sought before the selected course of action is implemented. (d) A recognition-primed event in which the selected course of action is judged as unsuitable and another is selected.

a changing context, recognizes its typicality, and selects a course of action, but then, after mentally simulating the outcome of that action, decides it is not a suitable course of action. He selects a new course of action, but that also fails the mental simulation test. The third course of action passes, and he implements that.

Discussion

This review of the two models suggests that the differences between the recognition-primed decision model and the decision ladder are not as substantive as they might first appear. The idea of a restricted set of cognitive states and processes is contained within each. Although the labels used to refer to those cognitive states and processes differ, the concepts to which they refer are similar. The standard decision ladder fails to account for some specific aspects of recognition-primed decisions but can be updated to accommodate the insights developed within the naturalistic decision research. The recognition-primed decision model fails to take explicit account of rational processes, but this is a matter of emphasis rather than of neglect.

Neither of these approaches is fundamentally constrained in a way that would prevent practitioners from drawing on aspects of the alternative approach to strengthen their own analysis. Thus, those employing one approach can benefit from exploiting insights available from the other. The completeness and the symmetry of the decision ladder offer a useful guide to consideration of all potential cognitive states and processes involved in any work task. Recognition-primed decisions can be mapped onto the updated decision ladder, and the benefit of doing so is that the exploration of alternative paths (both actual and feasible) is encouraged.

The substantive difference between these two models lies in their foundational assumptions for analysis and design as contained within their overarching frameworks. Cognitive work analysis, of which work (control) task analysis is a part, is framed as a systems approach to the analysis and design of the sociotechnical aspects of complex, large-scale systems. From cognitive work analysis one gets the emphasis on the structural work constraints as a means of breaking the task-artifact cycle.

In contrast, decision-centered design, of which recognition-primed decision making is a part, is framed as an approach for identifying potential points of leverage in the design of systems supporting situation awareness, decision, and planning. From naturalistic decision making we get the emphasis on actual, noteworthy events as a powerful means of eliciting information from workers about subtle aspects of expertise.

Restricted projects with limited budgets and goals that focus on the design of cognitive supports for particular types of work tasks will benefit from use of the decision-centered design framework. In contrast, an acquisition framework such as that employed by the U.S. Department of Defense for development of major weapons systems will benefit from both (Lintern, 2009a).

The systems perspective of cognitive work analysis promotes identification of the functional structure of the work domain, the outcomes to be achieved, the definition of human work roles, the collaborative processes that facilitate transactions between people (and also between people and artifacts), and the cognitive tasks and strategies to be used in the execution of the work. The decision-centered perspective promotes judicious application of knowledge elicitation tools to identify problem areas in current work practices and to isolate leverage points that offer opportunities for high-value (but often low-cost) interventions. Each of these cognitive frameworks can play a substantive role at different stages in the acquisition cycle for development of a complex, large-scale, and transformational first-of-a-kind system (Lintern, 2009a), and so the decision analysis strategies considered in this paper, being essential elements of their respective frameworks, will similarly contribute to the overall outcome.

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Gavan Lintern has a PhD in engineering psychology (University of Illinois, 1978). His recent research employed cognitive work analysis to identify cognitive requirements for complex military platforms. Gavan retired in 2009. He now works occasionally as an industry consultant and runs workshops in cognitive systems engineering, otherwise filling in as minder of the home pets and general home roustabout. He published a book, *The Foundations and Pragmatics of Cognitive Work Analysis,* in April 2009.