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Title: Cognitive Constructs and the Sensemaking Process

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Abstract

Battlefield realities seldom match the notional planning assumptions against the adversary during combats. This is because of the shifting and changing strategies of the adversary. This situation is even worst under the non-traditional adversary (NTA) conditions where planning takes place in the same mode as operations---leading to **plan-as-you-execute (PAYE)** conditions. The PAYE paradigm, then, captures the reality of coping with the dynamics of the NTA battlefield conditions, such as, evolving, asymmetric, and overwhelming complex information. This paper presents the cognitive models that influence the enactment of a dynamic sensemaking process using the PAYE model.

1. INTRODUCTION

Some of the most fundamental aspects of human cognition are the ability to reason, recognize patterns, compare facts, differentiate between "what makes sense" and what doe not, and make decisions. All or some of these cognitive tasks can take place simultaneously—sometimes inherently without our notice. More so, it can be applied to different problem solving situations –from the mundane to more complicated situations.

These cognitive characteristics make the commanders to face the battlefield realities which seldom match the notional planning assumptions against the adversary during combats. This is because of the shifting and changing strategies of the adversary. This situation is even worst under the non-traditional adversary (NTA) conditions where planning takes place in the same mode as operations---leading to **plan-as-you-execute (PAYE)** conditions. The PAYE paradigm, then, captures the reality of coping with the dynamics of the NTA battlefield conditions, such as, evolving, asymmetric, and overwhelming complex information. The existing OODA (Observe, Orient, Decide, Act) model developed by Boyd (1987) and commonly used by the military to capture iterative courses of action planning and decision making is not robust to capture adaptive, agile, and time-phased sensemaking process since it was not designed to address changing contexts and shifting strategies of the opposing force, especially, in asymmetric conditions where the enemy is spatio-temporally distributed and embedded in the civilian populations. The PAYE paradigm is designed with the aim to improve on the OODA model by capturing multi-phases of sensemaking enactment and decision making cycles along a continua of multiple and simultaneous operation cycles. This paper presents the cognitive models that influence the enactment of a dynamic sensemaking process using the PAYE paradigm. This paper does not claim any finality on the selected cognitively-enabled models reviewed. The contribution of each model in the sensemaking process is presented.

2. COGNITIVE CONSTRUCTS IN SENSEMAKING

2.1 How Cognitive Constructs Evolve During Sensemaking

When we encounter a new situation we reason around it; when we find a shortcut or dead end we remember it—we learn it. We try to make sense of information and the situation confronting us through many phases of knowledge processing of which the majority is cognitive. The modalities are, in the simplest forms, process information of epistemological and ontological natures (Dretske, 1991). For example, through a system of question-answering dialogues, one can reason, describe, derive, and predict consequences of situations. A collection of question-answering elements in a conversation, problem –solving, and other forms of inquiries, queries, and postulated discourse captures the evolution of the cognitive tasks; and they do so as a dynamic process that is situation-specific. An example of the general characteristic of such a system can be described using epistemologically mediated queries:

(a) The "who" is the culprit resource used for role assignment.
(b) The "how" is the procedure or the formation of process knowledge.
(c) The "what" has been and will continue to be the irrefutable epistemological question used to instantiate the reasoning process. In philosophy, it is the arbiter for probing into "what if", "what next", and so on.
(d) The "why" is the voice of reason and explanation. It is something experienced and expressed either explicitly or implicitly.
(e) The "which" is the guiding post to evaluation of capabilities, capacities, and availability.
(f) The "when" is the idea or an expression of the concept of time. It can be elusively stochastic, but can be anticipated by indexing events to time of occurrences—episodes, scenes, and schedule of activities.
(g) The "where" relates to the geo-spatial dimensions and their relationship to tasks, and people locations; these may be distributed locally or away in some distant. For example, in the battlefield scenario, if the adversary is known, the geographical mobility can be traced or at least mapped through hypothetical areas of interest.

All the processes (a-b above) depend in part on the framework of cognition and the representation of knowledge ascribed to schema.

2.2 Cognitive Schema Theory

Sensemaking has both intrinsic and extrinsic properties derived from cognitive models and theories. An individual's cognitive model represents the intrinsic properties. Whether it is the individual or organization, the dimension of sensemaking properties can range between relatively flexible and relatively rigid, depending on the density of available cognitive schema. This property depends on such knowledge factors as tacit knowledge, task contexts (environment) and the related required human actions and activities, level of human expertise which helps to frame the understanding process about the situation.

Bartlett's (1932) concept of a schema as a relational structure of information concepts across abstraction boundaries seems to be a useful in describing the intrinsic and extrinsic properties of sensemaking as alluded to above. Geiselman and Samet (1980) note that a schema constitutes the basis for how what we know is categorized, selected, deleted, abstracted, consolidated, and organized in the memory. An organization of information represents an important aspect of the sensemaking process. Each schema is assumed to hold a specific knowledge or data category in a slot or slots. Information in the slot is analogous to a particular level of abstraction.

Hintzman (1976) identifies three types of schemata: functional, cognitive, and conceptual. A functional schema holds the knowledge humans use to cope with everyday task. Above the functional schema, is the cognitive schema which operates as atypical knowledge, that is, knowledge based on beliefs and stereotypes. For example, people express their goals and intentions based on prototype beliefs anchored on strongly held information about a context. The contextual schema is used as a meta-cognition schema, that is, as an executive supervisor to the cognitive schema. Meta-cognition schema organizes knowledge based on high level concepts, percepts, and categories (Scholl, 1987).

A schema is viewed by many psychologists as a recognition memory device because of its ability to store object attributes as surface knowledge, thereby making its retrieval automatic (Hintzman, 1986). The surface structure of working memory corresponds to the cognitive and functional knowledge held by human experts to respond to familiar environment, or restructure the atypical stereotypical knowledge to unfamiliar situations.

Because of the above assumptions, a schema-based organization of knowledge links automatic inference with mental models of the context stored in the human memory. This characteristic allows a schema to be applied in many situations involving information organization. Smallwood (1967) has used schema slots to describe the internal models held by pilots during instrument monitoring. Downs and Stea (1977) and Scholl (1987) have used schema organization of information to develop computational models of cognitive maps. Geiselman and Samet (1980) and Noble (1989) have applied schema theories to summarize military information and to elicit situation awareness information from the memory. There are also algorithmic schemata that allow the mapping and association of concepts for assessing higher level production knowledge that store spatial information about concepts with graded level of constraints.

Based on the nature of the sensemaking properties, cognitive schemata provide the focal point for understanding the varieties of, and the process for organizing information during the sensemaking process. A cognitive schema contains the features or attributes that are associated with a category membership. These schema types include, e.g., person schemata, event schemata, and role schemata which supports such cognitive tasks as diagnostic problem solving and prediction. :

Bloom's cognitive taxonomy (1956) offers an aspect of describing cognitive constructs and their relevance to the sensemaking process. This is elaborated in Table 1. As more discussion is presented in this paper, the usefulness of Bloom's cognitive taxonomy becomes more clear and distinctive.

Table 1 Sample Matrix of Sensemaking Cognitive Schema Derived from Bloom's Taxonomy

Bloom's Cognitive Schema (tasks)	**Basic Skills / Human Performance**	**Intermediate Skills/ Human Performance**	**Expert Skills/ Human performance**
Cognitive Readiness: • Conceptual level • Knowledge of specifics • Knowledge of universal abstractions such as standards and terminology	General attention, memory, & central processing , fine motor control such as using computer mouse: speeds and errors	Conceptual reasoning, divided attention, auditory & visual processing: speeds, errors, etc.	Respond inhibitions, sustained attention, visuospatial classification and sequencing,

			visual tracking: errors, error rate, speed, etc.
Comprehension of environment: • Translation of command & control (C2) intent • Interpretation of C2 goals • Extrapolation of C2 goals during uncertainty and novel situations	Organizational level language learning, auditory and visual processing, working memory: speed, time, errors, etc.	Dual task paradigms, divided attention: error rate, number of errors, speed.	Advanced language for human-computer interface, use of special codes for security protection: number of violations, errors, error rate, etc.
Sensemaking of Battle Information: • Discovering relationships between distributed C2 levels. • Recognizing enemy messages from friendly. • Emerging organizational principles into virtual C2 •	Similarity matching based on information features: errors, speed, accuracy, etc.	Pattern recognition based on information objects, maps, link analysis, and other forms of spatial representations: errors, speed, accuracy, duration, etc.	Random search and stochastic pattern matching based on evolving situations: speed, error rate, accuracy, synchronization of actions, etc.
Information Fusion (Synthesis): • Production of a unique battle plan • Production of resilient communication across all spectrum of friendly network	Using information to develop deliberate plan structure, understanding basic battle process: errors, accuracy, etc.	Fusion of various information patterns, choice of automation aids to facilitate communication modalities: degree of fit, errors, accuracy, speed, etc.	Coalition information fusion, non-deterministic evolving plans based on novel incidents, ability to override automation aids: speed, response inhibition, working memory, etc.

3. COGNITIVELY-ENABLED CONSTRUCTS SUPPORTING SENSEMAKING

3.1 Cognitive Maps

A cognitive map (CM) consists of information relationships which may graphically represent events, processes, or operations in the form of psychological transformations and causality models. It represents how the micro elements of cognition are linked as we reason about a phenomenon---such as when an individual acquires, codes, stores, recalls, and decodes information about relative locations and attributes of phenomena in everyday spatial environments. Cognitive maps allow people to frame issues or work on complex problems with a web of extraneous relationships

Theories of expertise surmise that experts have mental models of a situation and the mental models can be used to reconstruct past reflexive knowledge and conceptually use it as a predictive model of a new situation (Simon and Hayes, 1976). For a mental model to be useful, the information "dots" or footprints with the model space has to be connected spatially through some conceptual linkages, correlations, or by using some metrics of relatedness. One way of connecting such relational conceptual "dots" is the cognitive map. A CM is generally described as a map of a process composed of a series of psychological transformations by which an individual acquires, codes, stores, recalls, and decodes information about the relative locations and attributes of phenomena in his or here everyday spatial environments. Cognitive modeling is based on causal mapping of cause-effect relationships to capture relational concepts—some which may be correlated, and some may have only abstract relationship (Eden, 1988). Table 2 gives an anecdotal summary of the selected definitions.

Table 2. Selected definitions of cognitive map

- Mental models of the relative locations and attributes of phenomena in spatial environments (Downs and Stea, 1973).
- Internal representation of experienced world, including cognitive tasks and use of information (Gibson, 2001).
- Anticipatory schema for search, sampling and interpretation of information based on experience (Neisser, 1967).
- Clusters of knowledge landmarks and routes that form minimaps (Sternberg, 1999).
- All elements of physical space with cognitive counterparts (Huff, 1992).
- A spatial mental model (Eden, 1988).

A CM can be represented as a diagram and as a matrix. The diagram representation is used for capturing cause-effect relationships in an organization or situation, because it is easy to see how each of the concepts relates to each other. Matrix representations are used for identifying the most effective causal path because it is convenient to apply a mathematical algorithm. When represented as a graph network, the nodes may represent a concept, a framework, or generic object definition with its attributes; the arcs of the network represent relations, conceptual dependency, correlation, or any other metrics of important for relational definitions. Cognitive maps can also be used as tools for improving understanding of system modeling and problem solving, one's own thinking patterns, and the thinking patterns of others. This can be useful to improve self-analysis or communication with others and to conceptualize and analyze complex phenomena in systematic ways. Figure 1 illustrates a simplified example of a cognitive map of a commander receiving a report of shooting in his area of command.

3.2 OODA Model (Boyd, 1987)

The OODA (Observe, Orient, Decide, and Act) model was developed by Boyd (1987) to address the concerns of military decision making process that considers

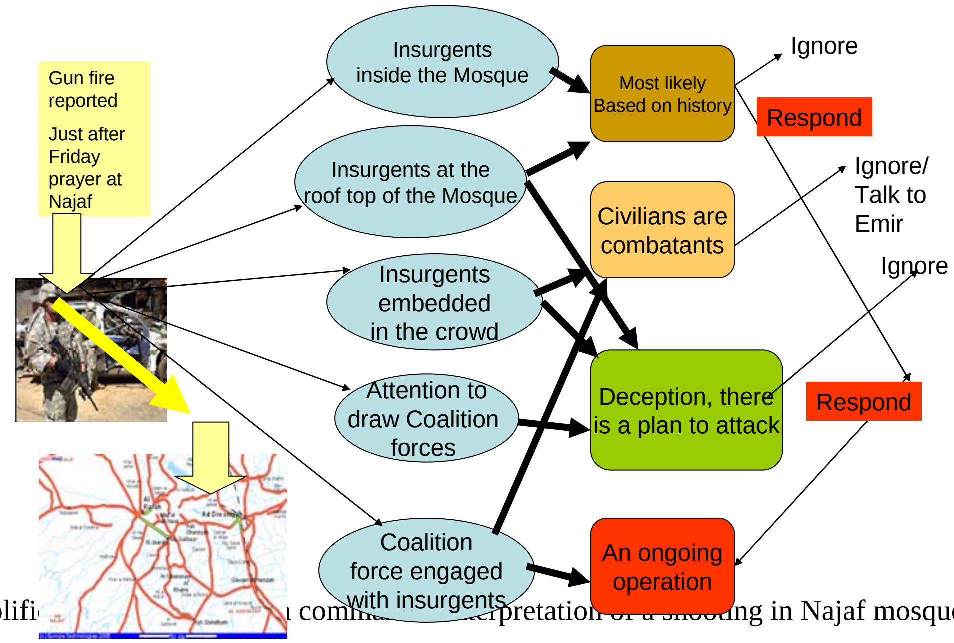


Figure 1. Simplifi… comm… interpretation of a shooting in Najaf mosque in Iraq.

uncertainties. In the OODA model, the "Orient" sub-model attempts to capture the cognitive processes involved during sensemaking—although it was never addressed as such. The generic OODA model is shown in Figure 2. The components describe the following cognitive tasks with feedback and feed-forward loops.

Observation – This entails the data collection process using human and technology sensors.
Orientation – At this stage, the collected information is used to form a mental image of the circumstances. Here, data is converted to information, and information is converted to knowledge. These products are stored into adaptable schema codes which are later used to "deconstruct" old images and then "create" new images. This orientation emphasizes the context in which events occur for use in the understanding of future system states.
Decision – This task involves analysis and selection of potential courses of actions for execution.
Action – This phase addresses the notional requirements for execution and evaluation of the expected consequences of the action. The evaluation loop is responsible for the feedback through "lessons-learned" made possible through data collection from realistic situations.

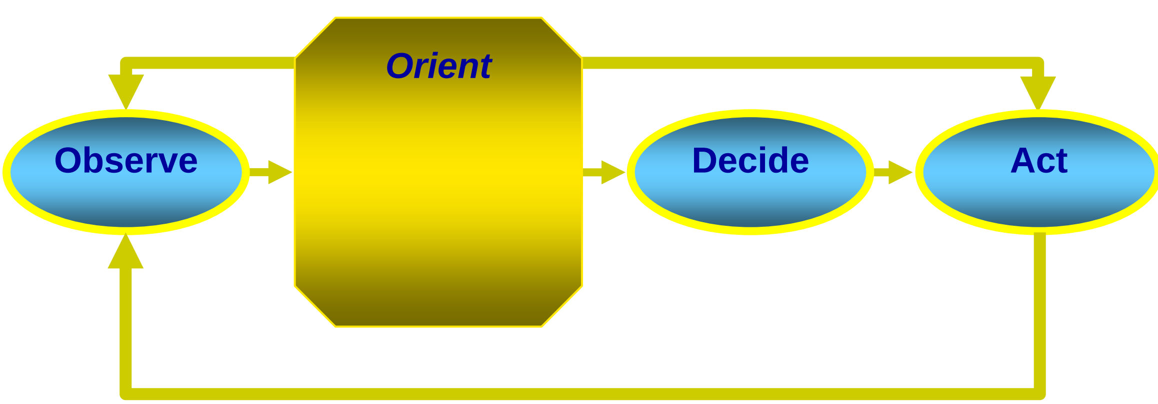


Figure 2. The classical cognitive structure of the OODA model.

3.3 Dynamic Model of Situated Cognition (Shattuck & Miller)

Sensemaking can be viewed as a sequence of situated acts. Situatedness (Clancey, 1997; Suchman, 1987) holds that “where you are, when you do, what you do matters”. Thus, situatedness is concerned with locating everything in a context so that the decisions that are taken are a function of both the situation and the way the situation in constructed or interpreted. Because situations may change over time, the cognitive processes required to adapt to such changes must be dynamic. This change is dependence on the constructive memory which holds that memory is not a static imprint of a sensory experience, but is subject to continuous changes due to new information stimuli (Dietrich and Markman, 2000). The sensory experience is stored and the memory of it is constructed in response to any demand on that experience.

Shattuck and Miller (2004) describe a dynamic model of situated cognition (DMSC) in which data flow from the environment, through sensors and other machine agents to the human agents in the system. This approach overcomes the biases which are inherent in analytical methods focusing almost exclusively either on machine agents or on human agents. The DMSC posits that there are various stages of technological and cognitive system performance (see Figure 3). On the technological side, all the data in the environment, data detected by technological systems (e.g., sensors), and data available on local command and control systems (C2; e.g., workstations) are included. Each of these stages includes a subset of what was included in the preceding stage. Building upon this technology are the perceptual and cognitive systems offered by the human operator.

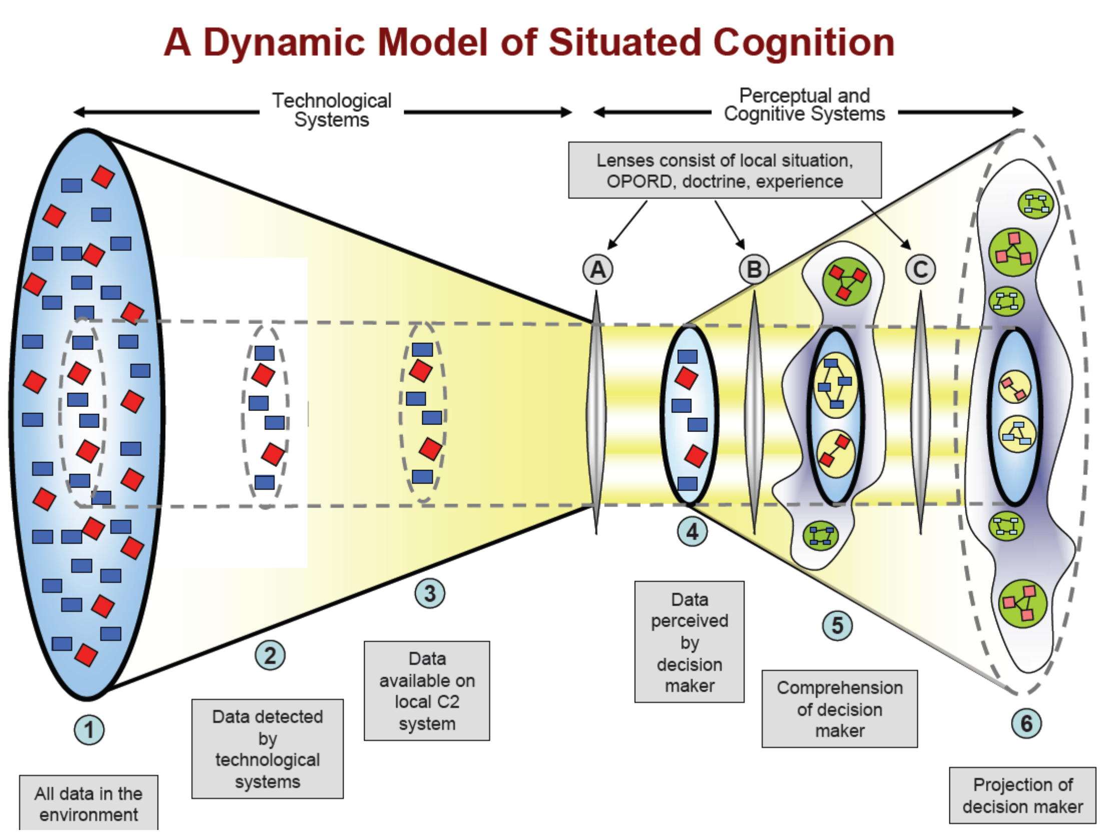


Figure 3. A dynamic model of situated cognition (Courtesy of Shattuck and Miller, 2004)

3.4 Situation Handling Model (Wiig, 2002)

According Wiig (2002), sensemaking is a continuous integration of evolving situation handling activities that are cast on a malleable concrete of cognitive activities. This requires, for example, mental reference models, concepts formed around situations of interest, the volition act of trying to understand the situation relevant to the available information, the thirst to make useful and flexible judgment of events and activities based on principles, facts, and theories of the universal constructs. Figure 4 illustrates Wiig's prima facie cognitive constructs of the situation understanding process.

In Figure 4, it is assumed that people possess most situation handling knowledge in the form of mental models. The four types of mental models are:

(1) **Situation Recognition Models** are used for Sensemaking and provide characterizations of memorized events and are recalled when comparable situations are perceived. People possess large libraries in the form of schemas with tens of thousands of situation recognition models that incorporate encoded information of situations they have encountered in their life.

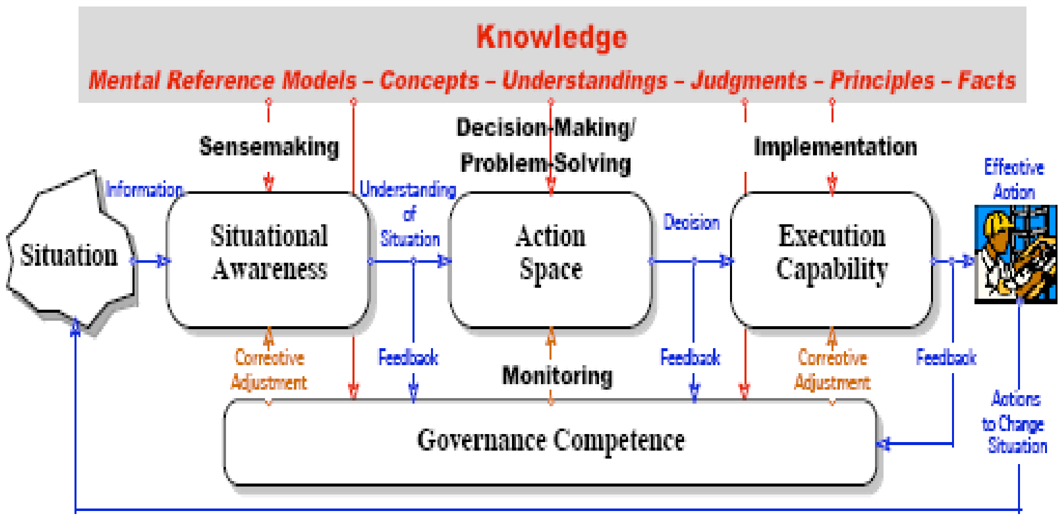


Figure 4. Personal situation-handling (Wiig, 2002: Knowledge Research Institute)

(2) **Decision-Making and Problem-Solving Models**. Consist of a mental library of reference models that covers a large domain and guides the decision-making /problem-solving process . These mental reference models range from quite concrete action models to abstract and meta-knowledge models. They provide simple rules for handling of routine and well known situations by rote, to procedures for more complex situations which may need creation of innovative actions, to methodologies for problem-solving in novel situations. Selections of which mental models that are called into action depend on the level of situation familiarity and understanding that resulted generated from sensemaking activities.

(3) **Execution Method Models** are used to provide guides to implement the desired action generated by courses of action planning exercise. Many Execution Method Models are complicated and take into account trade-offs between available resources and decision objectives. Some also include aspects for how to deal with constraints of different kinds. All seem to provide dynamic perspectives on the evolving implementation process.

(4) **Governance Approach Models** are used for monitoring and provide both principles and guides for evaluating the situation-handling progress. These models contain goals and objectives for the particular situation that is handled.

3.5 Situation Awareness Model

Endsley (1995) defines situation awareness (SA) as the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future. This definition lends itself to defining specific levels of situation performance:

- *Level 1 Situation Awareness*: perception of the status, attributes, and dynamics of the individual task-relevant elements in the environment;
- *Level 2 Situation Awareness*: holistic comprehension of the current situation, based on a synthesis and understanding of these elements in light of one's goals; and
- *Level 3 Situation Awareness*: projection of the future actions of these elements in the environment, at least in the very near term.

The SA model, then, enables the users to visualize information so as to enable real-time prediction of the system states in time and space (Endsley, 1995). This is shown in Figure 5.

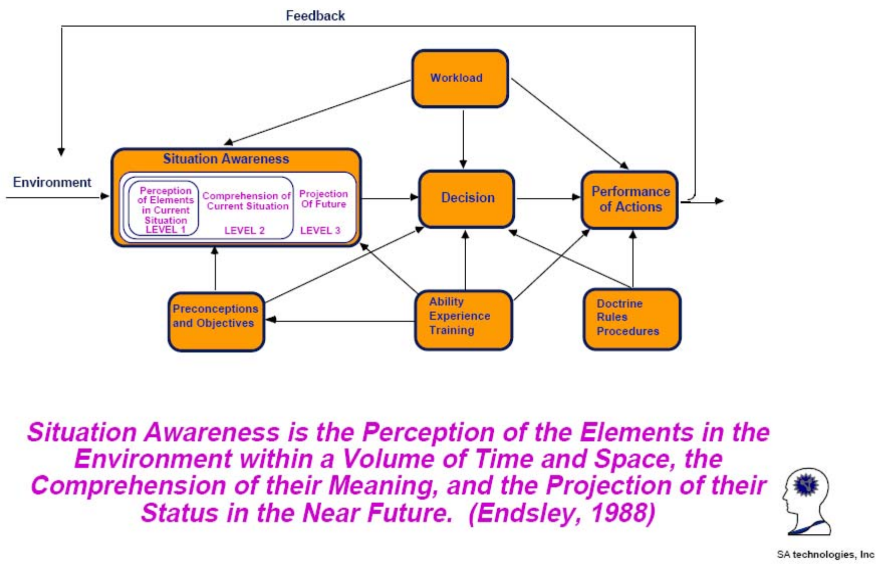


Figure 5. Elen

Each of the levels identified above needs specific cognitive structures to deal with information processing at different levels of information abstraction (Ntuen, et al., 2004). These are:

Level 1 SA: Perceptual control or operational cognition
Level 2 SA: Quasi-cognitive control or doctrinal cognition
Level 3 SA: High level cognitive control or meta-cognition.

Perceptual control corresponds to skill-based behavior which operates on the environmental information. Because perceptual control is a self-referenced operation, the process of corrective feedback is mediated by internal mechanisms responsible for perception. The applicable notion of perceptual knowledge is the time-invariant model of total awareness, shown to be enabled by cognitive properties of mental activities (Johnson-Laird, 1983). Quasi-cognitive control (QCC) corresponds to rule-based control behavior. QCC depends in part on a collection of behavioral and analytical models of the process to be controlled. The models of the process can be represented by rules and conditions satisfying the constraints of the system. Hammond, Hamm, Grassia and Person (1987) have experimentally validated the concept of quasi-rational cognition and found that human control behaviors vary in switching between modalities of mental models and the information presentation availability. High level cognitive control is knowledge based. It is a result of human interaction with the environment and task, and is a function of such attributes as experience, competence, learning, and mastery. Polyani (1967) ascribe high level cognitive control to the contents of human mind, especially tacit knowledge. According to this view, human behaviors have direct association with the material content of the mind, thus making high-level control behavior time invariant. More importantly, high level cognition allows the human operator to reason, think, and have control of what is happening around him by providing short cut, run-time solutions to immediate and unpredictable problems.

3.6 The Data / Frame Model

Framing indicates how we structure problems into a particular set of beliefs and perspectives that constrain data collection and analysis. The framing usually narrows information search around local outcomes as opposed to issues further distant in effect. For example, an analyst may frame a solution for short run gains, disregarding long term consequences of the decision. Sensemaking involves putting stimuli into some kind of framework (Starbuck and Milliken, 1988).When people put stimuli into frameworks, this enables them to “comprehend, understand, explain, attribute, extrapolate and predict.” Frames and cues can be thought of as vocabularies in which words are more abstract (frames) include and point to other less abstract words (cues) that become more sensible in the context created by the more inclusive words.

Sensemaking is a valid way to frame aspects or map cognitive behavior; reciprocal process of finding a frame for data and using a frame to define the data. Here, as postulated by Sieck, et al. (2004), military data will go through the military frame of reasoning, economic data will go through economic models, and political data will go through political frame, and so on. The frame paradigm is therefore sensitive to context, which makes it possible to capture the dynamics and continuity of information changes in the domain context. This is shown in Figure 6

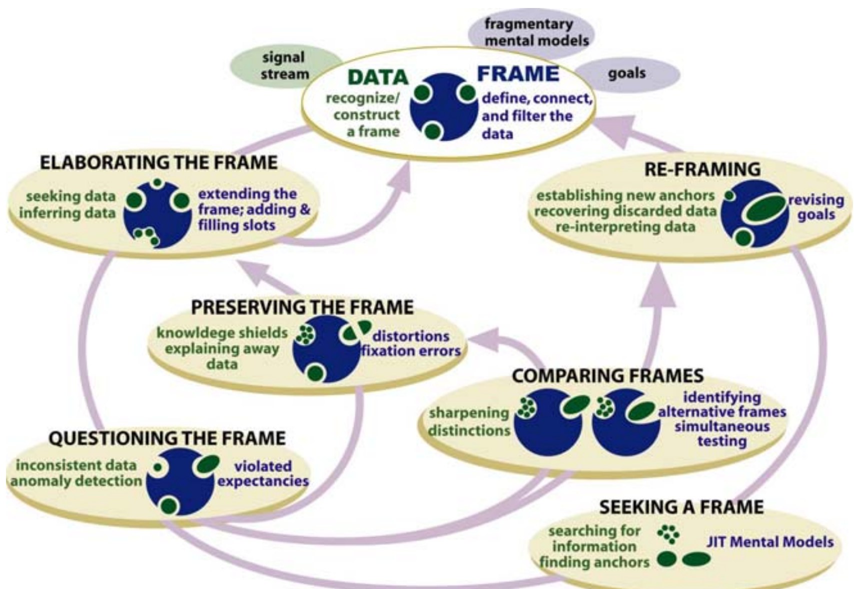
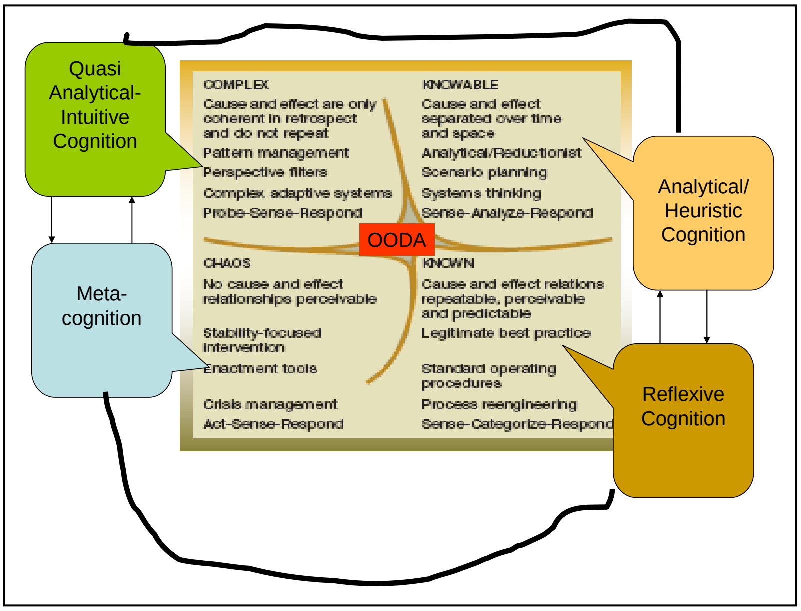


Figure 6. Frame/data model (Sieck, et al., 2004)

According to Sieck et al, “The purpose of the frame is to (1) define the elements of the situation, (2) describe the significance of these elements, (3) describe their relationship to each other, (4) filter out irrelevant messages while highlighting relevant messages, and (5) reflect the context of the situation, not just the data.” Further, they note that, interplay in terms of six specific cognitive activities that can elaborate, question, preserve, compare, seek, or reinterpret essential elements of an explanatory frame. These six functions of sensemaking serve to construct, maintain, and continually adapt the frame so as to provide the best interpretation of the current situation.

3.7 The Cynefin Model (Kurt and Snowben, 2003)

The Cynefin model is a sensemaking framework, which emphasizes the effect of problem type and environment on the sensemaking and decision-making capabilities. The Cynefin model has been shown to help sensemaker's to break out of old ways of thinking and to consider intractable problems in new ways—especially problems that are new and novel to the sensemaker. Figure 7 shows a Cynefin model with my addition of the cognitive elements required for the sensemaking process. I have also added the OODA model at the epicenter of the Cynefin architecture to illustrate the cyclical/iterative continuous feedback and feed-forward information sharing during the sensemaking process. There are four basic cognitive operational quadrants in the Cynefin model—each corresponding to the situation characteristics—from simple to chaos.



Ordered domain: Known causes and effects. Here, cause and effect relationships are generally linear, empirical in nature, and not open to dispute. Repeatability allows for predictive models to be created, and the objectivity is such that any reasonable person would accept the constraints of best practice. This region is rich in reflexive cognition—mostly remembered and familiar information is anchored on experiences and past histories.

Ordered domain: Knowable causes and effects. While stable cause and effect relationships exist in this domain, they may not be fully known. In general, relationships are separated over time and space in chains that are difficult to fully understand. Everything in this domain is capable of movement to the known domain. This domain is controlled by analytical cognition that is context specific and which can be developed heuristically using experience to cope with instances of flexible management of constraints.

Un-ordered domain: Complex relationships. This is the domain of complexity theory, which studies how patterns emerge through the interaction of many agents. There are cause and effect relationships between the agents, but both the number of agents and the numbers of relationships defy categorization or analytic techniques. Emergent patterns can be perceived but not predicted. Here, the type of cognition lies in a continuum of intuitive to analytic (Hammond, Hamm, Grassia, and Pearson, T,1987), and requires "cognitive agility."

Un-ordered domain: Chaos. In the first three domains we have described, there are visible relationships between cause and effect. In the chaotic domain there are no such perceivable relations, and the system is turbulent; we do not have the response time to investigate change. In this domain, meta-cognition is required to manage chaos and equivocality conditions. This can be described through the ambidextrous cognitive behaviors of the sensemaker.

3.8 Cultural Cognition Models

Boland and Tenkasi (1995) attempt to define sensemaking in terms as a process whereby a community of knowing develops and strengthens its own knowledge domain and practice-- a process where organizational knowledge emerges out of exchange, evaluation and integration of knowledge (Duncan & Weiss, 1979).

Cognitive psychologists (Sternberg, 1999) have identified that the human species has cognitive abilities with relatively superficial individual variations, directed to members of its group or society with whom they interact, cooperate, and compete. For example, how people think (natively versus globally) or act (politely or aggressively). Sociality and culture are made possible by cognitive capacities. These capacities span across many knowledge dimensions—moderating how we think, learn, adapt, discriminate, and decide, and so on; leading to a study in cultural cognition.

Cultural cognition is the study of what people can say about what they know (Hutchins, 1996). An example of a cultural model used in capturing team knowledge is story telling. Storytelling is a commonly recognized method for communicating visions, strategies, structures, identities, goals, and values within both organizations and cultures Stories also represent a powerful mechanism for communicating themes and evoking visual images. This can be expressed in terms of signs, symbols, or signals.

Signs, symbols, and signals also serve as artifacts of cultural identity and cognition. Figure 8 illustrates how the popular peace symbol is interpreted in Iraq and USA.

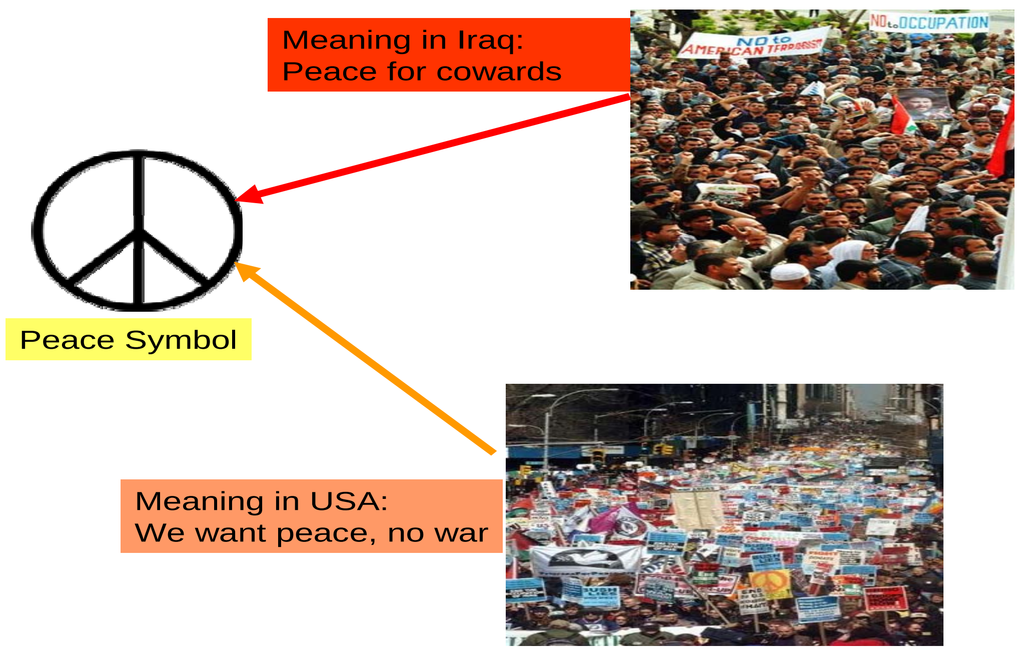


Figure 8. Sample cultural cognition of a universal symbol of peace

With a good understanding of cultural cognition, it is possible to affect the C2 modus operandi in a military coalition setting. For example, the decision makers will cope and appreciate the various types of organizational ignorance that may occur as a result of interpreting different cultural characteristics. Cultural models that govern the ways people interpret their experiences and guide actions in a wide range of life domains are required for this purpose. An especially important type of cultural model is a script (Schank & Abelson, 1977). A script is an event schema that stipulates the people who appropriately take part in an event, the social roles they play, the objectives they use, and the sequence of actions they engage in.

4. THE PAYE MODEL

4.1 Rationale

In the theory of sensemaking, it is difficult to distinguish between knowing and doing, since knowledge is an integral, self-sufficient substance, theoretically independent of the situations in which it is learned and used (diSessa, 1983). A situated action model maintains that the development of shared knowledge is a practical accomplishment by social actors using different kinds of tools that were developed through complex interrelations between culture, individuals and collectives. In this sense knowledge is reconstructed through human practice and the issue at stake for analysts is to describe how this is accomplished in different kinds of activities and contexts. Secondly the emphasis on action enables us to transcend the mind-matter dualism that characterizes empiricism and rationalism (Ryle, 1984). Meaning is tied to a specific context, and dependent on the sequential order of interaction. Cognitive issues such as remembering, reasoning, attributing and so on are reformulated as belonging to a social world of interdependent relationships. In modern battlefield planning environments, information changes so fast that notional planning models rarely survive the time between anticipated operation and the actual times the enemies operate—due to, for the most part, the high weight of uncertainties and chaos generated by the battle dynamics. It is therefore necessary to view modern battle planning system in the context of embodied cognition (Clark, 1999). The paradigm of embodied cognition enables the commanders to plan and execute their intended missions synchronously because the cognitive processes develop when a situation emerges from real-time, goal-directed interactions between agents and their environment; the nature of these interactions influences the formation and further specifies the nature of the developing cognitive capacities. That means that the sensemaking process must be viewed as a continuous and dynamically evolving human activity.

In this context, sensemaking is used as an embedded commitment tool for time-based information interpretation and situation understanding that allows the commanders to explain, use, and execute behavioral actions for which they are responsible when different situations unfolds. Human activities, actions, and levels of expertise are the things that must be assessed as a part of knowledge development for this kind of the sensemaking process.

A human action involves the voluntary act or will that manifests itself externally or that which may take place internally—both the explicit knowledge and tacit knowledge. A human action is also construed as being consequent upon planned behaviors (Allen, 1983; Searle, 1983) as formed by a sequence of causally related events. Changes in conditions of activity alter the method of achieving a goal (Leonard and Sensiper, 1998). If an activity is goal-directed, then, human actions should be formulated and planned to achieve a goal through performance of activities, in time and place, and when necessary without incurring excess cost. Incidentally, the required actions are inherently tacit within the dimension of the human expertise. On the other hand, human activity represents the explicit knowledge of translating tacit knowing into actionable knowledge. In this case, human activity can be divided into three components: orientation, executive, and evaluative. With this understanding, it is necessary to review the relevance of tacit knowledge in the PAYE model development.

4.2 Tacit Knowledge

Polanyi (1967) is repeatedly cited and credited for the definition of tacit knowledge and how it influences the sensemaking process. According to Polanyi, tacit knowledge is what is known but cannot be told. The reasoning behind the statement is that the knowledge has become so personal in the unconscious mind and therefore it cannot be expressed because there is no access to it through the conscious mind. Polanyi said *"we know more than we can tell."* Polanyi's concept of tacit knowledge is reflected in three main theses (Leedom, 2005): (1) true discovery cannot be accounted for by a set of articulated rules or algorithms; (2) while knowledge is public, it is also to a very great extent personal or constructed by humans; and (3) the knowledge that underlies explicit knowledge is more fundamental. Polanyi saw new experiences as always being assimilated through the concepts that the individual disposes and which the individual has inherited from other users of the language. Those concepts are tacitly based and form the background for all thinking. In each activity of thinking, there are two different levels or dimensions of knowledge involved that are complementary and mutually exclusive: focal knowledge (knowledge about the object, problem, or phenomenon that is in focus) and tacit knowledge (background knowledge that serves as a tool for improving what is in focus).

In dynamic terms, Polanyi observed that individuals acquire and use knowledge in many situations, and used the terms "knowledge" and "knowing" synonymously. As humans, we are engaged in the process of "knowing" all of the time, unconsciously switching back and forth between tacit knowing and focal knowing as the situation demands and as our attention shifts from one aspect to another. Also in a dynamic sense, knowledge relates to action-taking: knowledge is a tool by which an individual either acts or gathers additional knowledge. The skill with which an individual acts or gathers additional knowledge is a function of the meta-cognitive strategies the person uses to access and employ their tacit knowledge in order to shape and guide their focal knowledge. Kelly (1955) defined this phenomenon in terms of personal constructs, an individual's organization of unique mental models of the world that are both shaped by prior experience and are used to interpret new experiences. Though not admitted by Kelly as such, his Repertory Grid method is known today as a useful tool in the field of cognitive systems engineering.

4.3. The PAYE Model Architecture

The PAYE model is a collection of varieties of cognitive models discussed above. The model is dependent on schema-based knowledge representation about the world, a question-answering (Q-A) sensemaking query system (Ntuen, 2005), reflexive and reflective cognition models, and dynamic cognitive scripts or meta-cognition knowledge elements. Overall, the PAYE model is both time and activity driven. This makes it suitable for simulation experiments—both event-based and dynamic-based modeling and simulation formalisms. Figure 9 shows the component of the PAYE architecture.

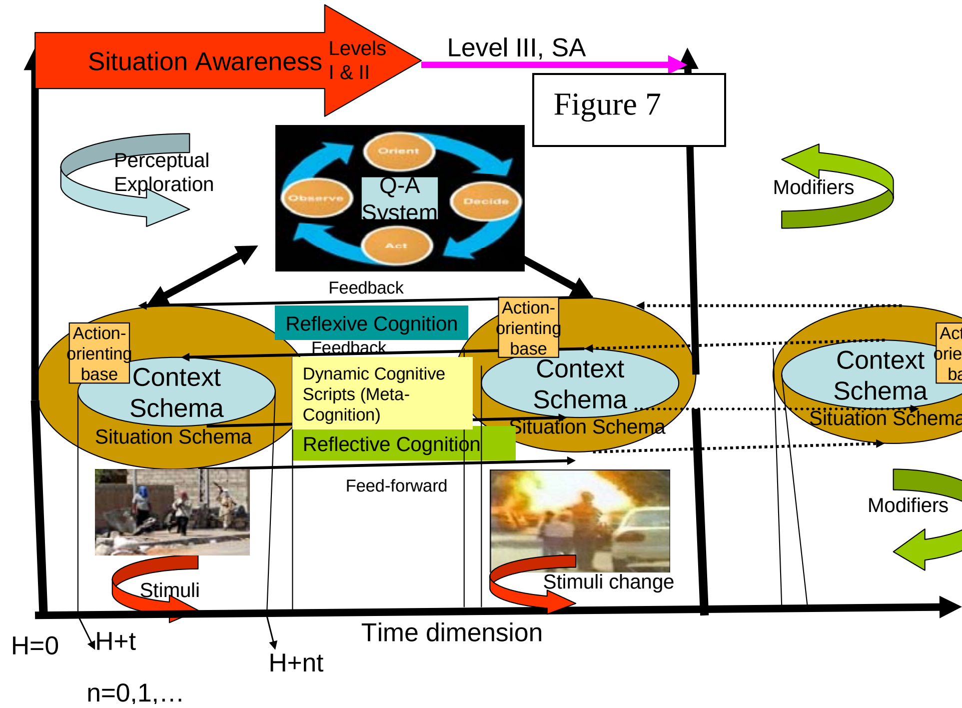


Figure 7

(a) Q-A Sensemaking Query System. The ultimate challenge of sensemaking is to build an understanding of the situation through question-answering (QA) chronology defined by epistemologically driven queries: how, why, when, which, what, and who. In the query system, the Q-A outcomes attempt to attach some properties to a given information situation or context. For example, consider a situation that is encountered by a military commander in Iraq. The following hypothetical Q-A dialogues may occur.

WHO: defines the entity or agent in question; e.g., Iraqi insurgents;
WHAT: defines the behavior of the agent; e.g., what the insurgent is doing or intent to do;
HOW: defines the activity or action performed by the agent or area of interest; e.g., the insurgent's tactics, such as using impoverished explosive device (IED);
WHERE: defines the location and geographical orientation of the agent; e.g., likely routes where the IEDs are planted;
WHEN: defines the time dimensions—qualitatively and quantitatively-- e.g. "before noon", "1300"; time of the day when the IEDs may likely be are planted or detonated;.
WHY: defines the explanation for the behaviors of the entities; e.g., the rationale for the insurgent's behavior—revenge, ethnic clashes, etc;
WHICH: defines specific information to focus on as an incumbent for further elaboration or questioning—through the process of identity marking; e.g., the insurgent may pick on specific population—Marines or civilians such as politicians who negotiate with USA..

The catalog of the Q-related information can be used to capture the sensemaking process: know-what, and the know-how which are the two main ingredients of tacit and focal knowledge (Polyani, 1967). Figure 9 is used to capture the information interactions from the Q-A query process.

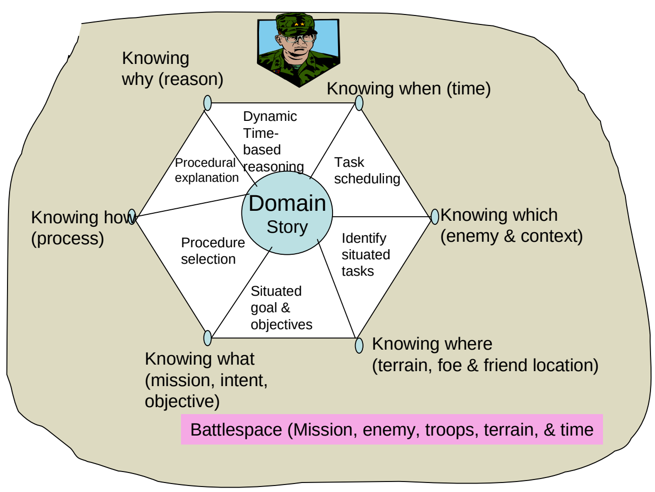


Figure 8. Cognitive elements of question-answering system in a sensemaking process.

(b) Reflexive Cognition: The purpose of reflexive cognition is to provide the expert (commander) with a self-evaluation metric in terms of competency and skill while dealing with complex or chaotic situations. It is anchored on past episodes, histories, and similarity of recorded events stored in the respective cognitive schema. For example, experience can suggest that we are more apt to solve a problem in one way rather than another, and so we reorder our cognitive tasks to try that first. Due to self-directedness or intrinsic feedback, reflexive cognitive tends to induce automatic information processing (Shriffin and Schneider, 1977) leading to retrospective planning strategy. Retrospective strategies have back up data and repertoire of past models making it easy for use in dynamically changing situations. "*A retrospective strategy is useful* *when the results structure provides sufficient guidance or knowledge accessing means (Hoc, 1988; pp. 77).”*

(c) Reflective Cognition. Reflective cognition allows the commander or the sensemaker to go beyond the simple recognition of successes and reach an understanding of the reasons for it, through awareness (Hoc, 1988) of the situation. Reflective cognition is the term used in cognitive psychology (Neisser, 1967) to describe conscious and thoughtful reaction to stimuli—it is a thoughtful activity requiring experience, expertise, skills, and ability. Reflective cognition is useful for generating prospective plans which force the individual to adapt a familiar procedure to the situation. Since the familiar procedure may not match the incumbent situation, a trial and error approach is enacted. Reflective cognition, therefore, is the result of interaction: our ability to learn new things come from encounters with the unexpected (that which lies outside our experience, that which is not part of our experiential cognition) that turn our path, leading to new knowledge: innovation.

(d) Meta-Cognition. This is a compendium of dynamic cognitive scripts –a generic footprint of events, activities, actions, episodes, and histories of experience with various situations, accumulated over many years by the expert sensemaker. Cognitive dynamics, observes Dietrich and Markman (2000, pp. 7) *“are many changes in an organism directly affecting that organism’s cognitive processing or cognitive capacities.”* These meta-cognitive activities may occur in various settings that may include, e.g., time frames, perception of task or environment complexity, levels of information processing such as those that are intrinsic to tacit knowing or socially shared knowledge. From Figure 8, the dynamics of cognition becomes relevance as the time dimensions and ecological niches transform occasions of situations to contexts, and vice versa. Table 3 below illustrates these time-controlled behaviors. Here, a situation indicates a momentary circumstances, conditions, or state of affairs. A context, on the other hand, is the circumstance which an event occurs.

Table 3. Time-controlled meta-cognitive activities

Ecological niches	**Time scale (H+nt; n=0,1,2,….)**
Situation	→ Situation (change/ unchanged)
Situation	→ Context (center of gravity, focus of effort, etc.)
Context	→ Context (change / unchanged)
Context	→Situation (evolved to higher task dimensions, complexity, and chaos)

As shown in Table 3 above, the changing dimensions of asymmetric battle information can force the sensemaker to the “edge of chaos” which requires the ability to think about “how to think right”—a meta-cognitive task. So, meta-cognition is associated to higher order thinking which involves active control over the cognitive processes engaged in sensemaking. Activities such as planning how to deal with IEDs used by insurgents in Iraq war, monitoring the behaviors of civilian enemies, and evaluating progress toward the completion of stability operation require the use of meta-cognitive. For example, the commander in Iraq may want to develop a profile of IED occurrence using a link analysis, incorporating time, place, events, etc. How to use the analytic information to defeat the enemy depends on the past cognitive schema or repertoire of knowledge accumulated by the commander over some time.

5. SUMMARY AND CONCLUSION

Sensemaking involves the use of the most fundamental aspects of human cognition which include, but are not limited to, the ability to reason, recognize patterns, compare facts, differentiate between “what makes sense” and what doe not, and make decisions. All or some of these cognitive tasks can take place simultaneously—sometimes inherently without our notice.

More so, it can be applied to different problem solving situations –from the mundane to more complicated situations. Cognitive theories, especially schema models of knowledge representation are seen as more robust devices to capture individual and group tacit knowledge since each schema is unique and more flexible to capture of new information. This paper has weaved together these existing cognitive models useful to sensemaking and extends their applications to situations in which the sensemaker considers planning and execution tasks concurrently.

The PAYE paradigm can also be considered to be a powerful cognitive architecture with many sub-models of cognition which interlace to support sensemaking development process in many varieties of situations. It is therefore necessary to view modern battle planning system in the context of embodied cognition as alluded to before. With this view, the commander can plan and execute their intended missions synchronously as a cycle of interacting plans-- that means that the sensemaking process must be viewed as a continuous human activity. It is believed that the PAYE model has the modules necessary to support both discrete or dynamic modeling and simulation of the sensemaking process. Either notionally or for practical training purpose, the PAYE model can also provide an open architecture to capture execution-monitoring phases of the battle space information characteristics. This capability can increase the possibility of adapting old plans to new contexts, or developing new plans concurrently with the execution and monitoring tasks. These are the basic characteristics that are currently lacking in the existing cognitive models such as the OODA model.

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