

ENRICHING EXECUTIVES' SITUATION AWARENESS AND MENTAL MODELS

A Conceptual ESS Framework

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Abstract: Regardless of cognitive orientation of increasing importance, most executive support systems (ESS) and other decision support systems (DSSs) focus on providing behavioural support to executives' decision-making. In this paper, we suggest that cognitive orientation in information systems is twofold: situation awareness (SA) and mental model. A literature review of SA and mental models from different fields shows that both the two human mental constructs play very important roles in human decision-making, particularly in the naturalistic settings with time pressure, dynamics, complexity, uncertainty, and high personal stakes. Based on a discussion of application problems of present ESSs, a conceptual ESS framework on cognitive orientation is developed. Under this framework, executives' SA and mental models can be developed and enriched, which eventually increases the probability of good decision-making and good performance.

1 INTRODUCTION

Decision support systems (DSSs) are computer-based information systems, which are designed to aid people in decision-making process (Shim, Warkentin et al. 2002). Executive support systems (ESSs), as a kind of DSS, serve the information needs of senior executives, especially in the strategic management process (SMP) (Rockart and Delong 1988; Pijpers, Bemelmans et al. 2001). The major function of today's ESSs is information delivery based on a central data warehouse or data marts. The delivered information can include critical success factors, operational data, ratios and other kinds of data that executives use to monitor the performance of the enterprise.

ESSs are data-oriented information systems with very limited support to strategic management process (Singh, Watson et al. 2002). An ESS is capable of providing executives with a huge amount of data, from internal and external environment of the enterprise, such as operations, marketing, accounting, sales, research and development. However, more data does not equal more valuable

information (Endsley, Bolte et al. 2003). Current ESSs can only partially support executives' strategic management process (Singh, Watson et al. 2002). Table 1 shows that only two out of five SMP stages can be supported or partially supported by current ESSs. Executives often feel lost when presented with a body of data concerning strategic decision-making. In a recent study (Economist Intelligence Unit, 2006), 73 per cent of senior managers in a survey agreed that it is important to have less but more timely data to improve the quality and speed of decision-making in their organizations. This result corresponds to Sutcliffe and Weber (2003)'s finding about the knowledge accuracy. Their research implies that having a lot of facts about a decision situation is less important than having a clear and consistent overview picture about it.

Cognitive orientation has long been recognized as an very important consideration in DSS research (Schwenk 1984; Yadav and Khazanchi 1992; Kuo 1998; Chen and Lee 2003; Chen and Ge 2006). Executives' cognitive ability (underpinned by their SA and mental models) plays a very important role in understanding dynamic complex business

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environments and dealing with ill-structured problems with time pressure, uncertainty and high personal stakes (Adams, Tenney et al. 1995; Endsley 1995; Chen and Lee 2003; Resnick 2003). SA and mental models are thought of as two essential prerequisites for people's decision-making in any dynamic complex system. Decision-making has a strong relationship with SA and mental models (Endsley 2000; Stanners and French 2005). High SA and mental models will increase the probability of good decisions and good performance.

Table 1: The ESS can only partially support SMP (Singh, Watson et al. 2002).

SMP Stages	ESS Support
Organizational objectives	Partial support
Environment scanning	Not support
Strategy formulation	Not support
Strategy implementation	support
Strategic control	Not support

The basic objective of this research is to improve the quality and quantity of support provided by ESSs through enriching executives' SA and mental models in terms of information systems. With rich SA executives is able to have a thorough comprehension about the status of the enterprise; with rich mental models they are more likely to make effective decisions efficiently.

2 COGNITIVE ORIENTATION IN ESS'S

2.1 Situation Awareness

The concept of SA was initiated from military aircraft domain and extended to air traffic control, nuclear power plants, and other tactical and strategic systems (Endsley 1995). In aviation, SA mainly refers to the pilot's knowledge about the aircraft itself and its environment (Emerson, Reising et al. 1987; Hamilton 1987; Vidulich 1995). Abstractly Sarter and Woods (1991) describe SA as:

Situation awareness refers to the accessibility of a comprehensive and coherent situation representation which is continuously being updated

in accordance with the results of recurrent situation assessments. (P. 52)

SA is believed to be a very important and essential prerequisite for people's decision-making in any dynamic complex system with time pressure, uncertainty, ill-defined goals and high personal stakes (Sarter and Woods 1991; Endsley 1995; Flach 1995; Smith and Hancock 1995; Endsley 2000). A close relationship exists between people's SA and their decision-making actions: The richer SA they have, the more likely are they to make good decisions (Stanners and French 2005).

In strategic decision-making domain, the same characteristics are shared as traditional SA application domains, e.g. aviation and power plants. Today's companies operate in a turbulent business environment where different sectors interact with and affect each other. Walters, Jiang et al (2003) provide an analysis of the environment to which the executive is subject during environment scanning for strategic management process. They summarize in 6 internal environment sectors (market research, product R&D, basic engineering, financial management, cost controls, and operational efficiency) and 6 external ones (market, technological, competitive, political/legal, economic, and socio-cultural). For the survival of the company, the executive needs to keep aware of each sector of the environment. Moreover, the speed and quality with which business strategies must be made has increased substantially with the trend of economy globalization. The complexity, uncertainty, dynamics, and time pressure of strategic decision-making show the potential of applying SA theory to support executives' decision-making.

2.2 Mental Models

Mental models are "psychological representations of real, hypothetical, or imaginary situations" (Johnson-Laird, Girotto et al. 1998). Mental models are commonly referred to as deeply held assumptions and beliefs that enable individuals to make inferences and predictions (Johnson-Laird, Girotto et al. 1998; Chen and Lee 2003; Chen and Ge 2006). Rouse and Morris (1985, p. 32) define mental models as "mechanisms whereby humans are able to generate descriptions of system purpose and form, explanations of system functioning and observed system states, and predictions of future states". Mental models are 'device models' by which people are capable of understanding how a device works in terms of its internal structures and processes (Sarter and Woods 1991).

Mental models is the key for a decision maker’s understanding of business environments and ill-structured problems. They provide executives with the ability to simplify the complexity of business environments (Schwenk 1984; Porac and Thomas 1990). Mintzberg (1973) categorizes executives’ work into 10 different roles and connects them with executives’ mental models. He finds that executives spend most of their time communicating with other people and thinking, by which their mental models are built based on their past experience. With rich and solid mental models, executives can envision possible future business scenarios that may cause problems or bring opportunities and then make appropriate strategies to respond.

Mental models and SA are different in their point of reference (Sarter and Woods 1991). Mental models use finite number of elements and algorithms to represent systems or devices, whereas SA is a dynamic representation of open systems. Mental models are about people’s past experience which are the basis and guidance for adequate situation assessments (Sarter and Woods 1991; Endsley 1995). Executives need both rich SA and mental models to understand the business environment, to

anticipate the near future status of the company, and then to succeed in strategic management processes.

3 A CONCEPTUAL ESS FRAMEWORK ON COGNITIVE ORIENTATION

In this framework of executive support systems (Figure 1), the basic idea is to aid executives’ decision-making through enriching their SA and mental models in terms of information systems. Because human decision-making has a strong relationship with SA and mental models, ESSs under this framework we believe will be able to thoroughly support executives’ strategic planning work.

Compared to traditional ESSs, three characteristics shape this system framework:

User-centered

The concept of user-centered is used for systems design. This concept means to put the user in the heart of all other considerations, such as decision situation understanding, data analysis, decision-

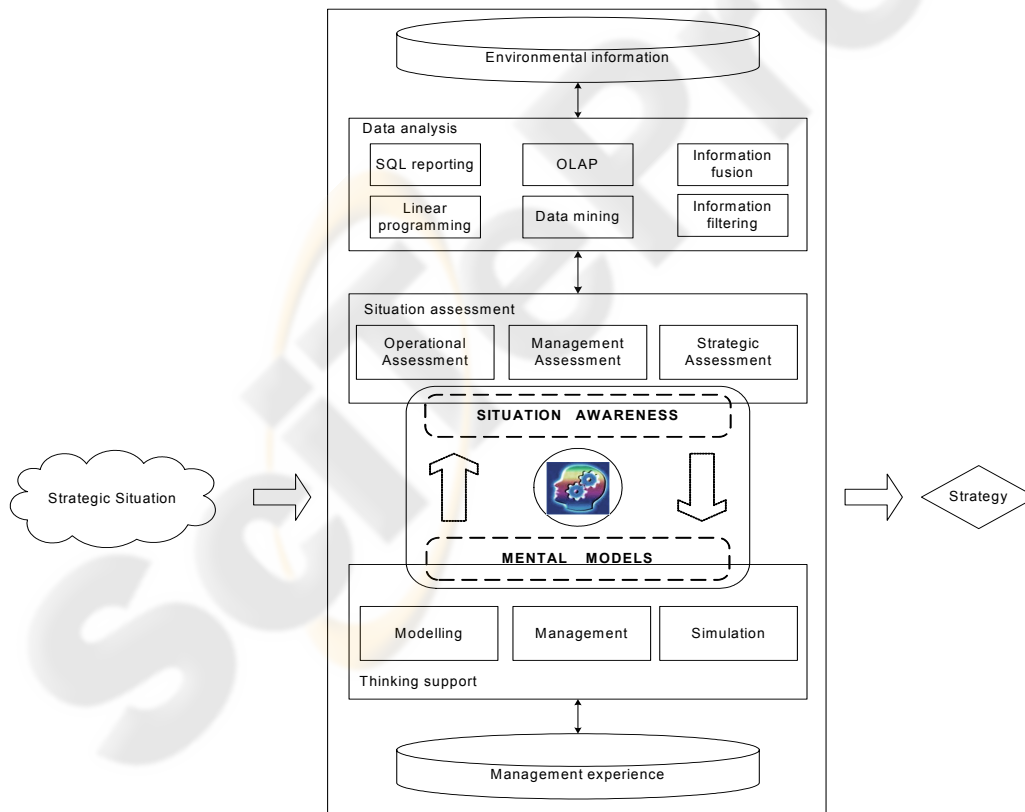


Figure 1: An ESS framework on cognitive orientation.

making etc. All the other theories, technologies and the system development will be researched, developed with the purpose of serving the user's requirements. The opposite end of the spectrum is technology-centered concept, where users need to adapt themselves to the data extracted by information system from the environment.

Cognitive orientation

Rather than emphasizing behavioral support to executives' work, we focus attention on cognitive aspects of management: SA and mental models. Based on Anthony's (1965) categories of management activity, we model executives' SA in three levels: operational, management, and strategic. The operational situation awareness (OSA) looks at the specific tasks usually conducted by frontline personnel as the basis of the operation of the organization. The management situation awareness (MSA) is concerned with middle managers' work assuring the acquisition and usage of the organization's resource in accomplishment of the organization's objectives. At the highest level, strategic situation awareness is about the top executives' strategic planning activities. In the strategic management process, strategies are developed and implemented, which translate the organization's objectives into pre-determined outcomes.

The three levels of executives' SA are developed or enriched through situation assessment module in this framework. Endsley (1995) proposed a conceptual model of situation assessment, whereby the operator's SA is developed through three steps: perceiving, comprehending and projecting. We also define three sub-modules of situation assessment with respect to three levels of executives' SA in our framework. Our framework has somewhat similarities with Endsley's model. Nevertheless, the three situation assessment sub-modules in our framework are not necessarily reflective of Endsley's three-step model. More importantly, the situation assessment module in our framework is designed from information systems perspective which we believe is more applicable to specific system development.

The functionality of situation assessment is fully supported by different data analysis techniques. Currently, six kinds of data analysis techniques are employed in this framework: information filtering, SQL reporting, OLAP (online analytical processing), data mining, mathematical modeling, and information fusion. Each of them contributes to different situation assessment sub-modules (Figure 2). The environment information data store is the

source that data analysis module processes. The environment information consists of internal environmental data (e.g. product R&D, financial, engineering, and marketing) and external one (e.g. technological, political, and socio-cultural). Both are important for executives' environmental scanning in strategic management process (Walters, Jiang et al. 2003).

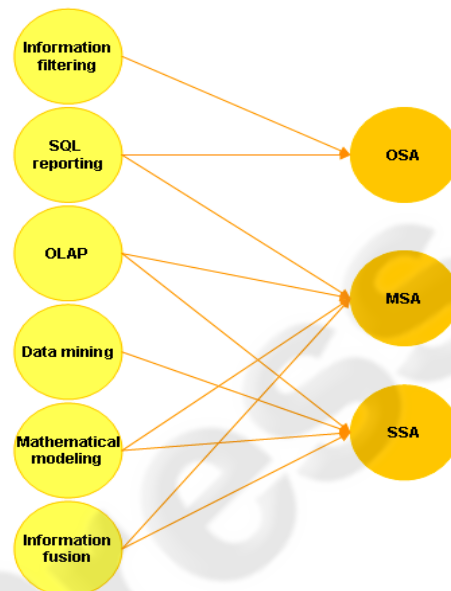


Figure 2: Data analysis techniques for SA.

Another cognitive aspect of this framework is thinking support through modelling, fusion and simulation of executives' mental models. We use cause mapping technique to represent executives' mental models. A cause map is a semantic network that consists of concepts (nodes) that are linked together by casual relationships (linkages). It helps executives to order their thinking process in strategic management process (Gnyawali and Tyler 2005). Mental models are a sort of mental construct within executives' minds reflecting their past experience. After represented as knowledge (information), multiple pieces of knowledge can be aggregated through fusion module in this framework, which makes it possible to facilitate the integration of different views from multiple board members. Mental models and SA are working together as the mechanism whereby executives are capable of anticipating future status of the environment. The simulation module in this framework is designed to enhance executives' abilities of projection. It includes the creation of business scenarios, what-if analysis, and the possible mental model simulation. Thinking support module is based on management experience store, which consists of executives' past

strategic management experience in difference cases.

Situation-strategy matching

In model-based decision support systems, a typical decision-making process consists of intelligence (identification of problems), design (generation of alternatives), and choice (analysis of alternatives). During this decision-making process, a computer system is mainly developed to deal with the structured portion of a DSS problem, but the judgment of the decision-maker was brought to bear on the unstructured part, hence constituting a human-machine, problem-solving system (Shim, Warkentin et al. 2002).

The decision-making process based on this framework is a situation-strategy matching process. In the strategic decision-making, the decision situation comes often with ill-defined goals, uncertainty, high stakes, and time pressure. And the decision problems are always too implicit and complex to be identified explicitly. In this case, model-based decision support systems seem ineffective. In our framework, proficient users (experienced executives) are playing the major role in decision-making process and computers are only used to help executives to enrich their SA and mental models. Because human decision-making has a strong positive relationship with SA and mental models, the experienced executives, equipped with richer SA and mental models, will be likely to perform better in strategic decision-making process.

4 DISCUSSIONS AND FURTHER STUDY

Compared to traditional decision support systems, this framework reflects a new DSS paradigm. However, some challenges emerge during the development of this framework.

Firstly, how to evaluate executives' SA? SA evaluation is important to systems design. Without effective evaluation methods, the executive's mind remains a black box for us and we are not able to be confident to declare that SA is supported. Endsley (1988; Endsley 1995) evaluates the pilot's awareness of the aircraft using so-called situation awareness global assessment technique (SAGT). In the SAGT, the pilot is flying a scenario in a simulation. The simulation system is frozen and the pilot is asked some questions concerning the current system status. The pilot's answers are then analysed to probe into his/her SA. SAGT is an intrusive

assessment technique for SA evaluation. There are also some after-the-fact methods such as debriefing, e.g., (Marshak, Kuperman et al. 1987). These SA evaluation methods are applicable to different domain, but are less likely to be effective in business SMP domain. In today's business environment, every company is focused on developing different competitive advantages. Each company is shaped by different goals, structures, processes, marketing share, and many other factors. The population of senior executives within each company is significantly small. Therefore, new SA evaluation methods need to be developed for business strategic decision-making domain.

Secondly, how to combine the theories of situation awareness and mental models and information systems techniques? Situation assessment is the process in which the executive's SA is developed. Present situation assessment models are mainly proposed in terms of cognitive psychology not from information systems perspective. The present business intelligence systems are mainly data/model-driven information/knowledge acquisition systems. Managers are usually either not enough confidence/experience to find out business solutions, or are just missed again in the new information flood provided by the system. One of the grand vision of DSSs should be human can interact with computer at a high degree and computer provides decision-maker cognitive supports. One of our next research tasks is to develop relevant theories and information technologies which can be used to aid executives' situation assessment.

Thirdly, how to facilitate an effect interaction between executives' SA and their mental models? The psychological mechanism on which SA and mental model are affected by each other has been researched and modeled from the perspective of psychology (section 2.2). Based on this framework, we will examine the relationship between SA and mental models in terms of information systems. Put simply, mental models look at the past, and SA looks at the present and the near future. Executives are able to achieve an overview understanding (big picture) of the company based on their SA; and then they identify the potential opportunities or threats based on their mental models. Therefore, to be successful eventually in strategic planning, executives will heavily rely both on SA, mental models, and their interaction.

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