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Assessing the Contributions of Cognitive Science to the Development of the Decision Support System Research Subspecialties

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Introduction

This paper reports a part of an ongoing study that systematically identifies the DSS reference disciplines and traces how concepts and findings by researchers in the reference disciplines have been picked up by DSS researchers to be applied, extended, and refined in the development of DSS research subspecialties. A macro-level examination of inter-factor correlations among the factors that emerged in this research revealed that cognitive science has strongly influenced the intellectual development of model management, user interface management, and implementation areas. This study focuses on examining the structure of DSS research with a particular emphasis on assessing the contributions of cognitive science to the development of model management, user interface management, and implementation.

Data

The primary data for this study were gathered from a total of 498 articles in the DSS area over the past five years (1991-1995). A citing article was selected if: (1) it discussed the development, implementation, operation, use, impact of DSS, or DSS components; or (2) for DSS articles related to contributing disciplines, they were explicitly related to the development, implementation, operation, use, impact of DSS, or DSS components. A total of 16,413 *cited* references taken from the 498 *citing* articles were added to the bibliographic database file created earlier. For a detailed description of data, see (Eom, 1996).

Research Methodology

This study uses author cocitation analysis (ACA). ACA is A technique of bibliometrics that applies quantitative methods to various media of communication such as books, journals, conference proceedings, and so on. The raw cocitation matrix of 104 authors is analyzed by the factor analysis program of SAS (statistical analysis systems) to ascertain the underlying structure of DSS research subspecialties.

Results

Factor analysis extracted eight factors consisting of five major areas of DSS research (group DSS, implementation, model management, design, and an unnamed factor) and three contributing disciplines (cognitive science, organizational science, and multiple criteria decision making). When compared to an earlier benchmark study (Eom 1996) which investigated the intellectual development and structure of DSS over the period of 1970 through 1990, this study reveals that the DSS area has undergone profound structural changes in the intellectual structure over the past five years (1991-1995).

Several DSS research fields/contributing disciplines are emerging. In the DSS subfields, design and implementation have emerged as the important fields of research. In the contributing disciplines, cognitive science is a new field appearing in this study. Two subareas of DSS research are disappearing-- individual difference and foundations. Group Decision Support Systems (GDSS) research has been strengthened and model management research has been a continuously central research theme. Organization science and multiple criteria decision making (MCDM) are steady fields of DSS contributing disciplines.

Factor 5 seems to represent Cognitive Science. The central component of cognitive science is the study of the human adult's normal, typical cognitive activities such as language understanding, thinking, visual cognition, and action by drawing on a number of disciplines such as linguistics, artificial intelligence, philosophy, cognitive psychology, neuroscience, and cognitive anthropology. The focus of cognitive science research is on how cognition typically works in normal adults, how it varies across individuals/different populations/cultures, how it develops, how it is realized in the brain, etc. (Von Eckardt 1993).

A theory of problem solving by Newell and Simon (1972) sheds some light on the understanding of how intelligent adults solve short (half-hour), moderately difficult problems of a symbolic nature such as those in chess, symbolic logic, and algebra-like puzzles. The kernel of their theory was described by four propositions (Newell and Simon 1972, pp. 788-789):

1. A few, only a few, gross characteristics of the human information processing system (IPS) are invariant over task and problem solver.

2. These characteristics are sufficient to determine that a task environment is represented (in the IPS) as a problem space, and that problem solving takes place in a problem space.

3. The structure of the task environment determines the possible structures of the problem space.

4. The structure of the problem space determines the possible programs that can be used for problem solving.

The study of human cognitive limitation has been another important area of cognitive science. Tversky and Kahneman (1982) described an aspect of human cognitive limitation-- cognitive biases that arise from the reliance on judgmental heuristics. They showed that people rely on several heuristic principles in making judgements under uncertainty (representativeness, availability of instances, and adjustment from an anchor), which are usually effective, but lead to systematic and predictable errors. Einhorn and Hogarth (1981) reviewed behavioral decision theory to place it within a broad psychological context. In so doing they emphasized the importance of attention, memory, cognitive representation, conflict, learning, feedback to elucidate the basic psychological processes underlying judgment, and choice. They concluded that decision makers use

different decision processes in different types of tasks. The decision processes are sensitive to seemingly minor changes in the task-related factors. Some of the contributions of cognitive scientists to individual differences/user interfaces and implementation research include the following.

(1) A foundational framework was presented to recognize many of the dimensions along which the total human system can vary (e.g., tasks, time scale, phylogenetic scale), although their theory was not concerned with personality variables (individual differences).

(2) The organization of the problem representation significantly influences the structure of the problem space and the problem-solving processes decision makers use. Therefore, when their problem-solving processes are adapted to the problem representation, decision makers make effective decisions, and this will lead to successful implementation of DSS.

(3) The limitations of the human information processing system (relatively slow serial processor with small short-term memory) and the cognitive biases contributed to the development of the ROMC (Representation, Operations, Memory aids, and Control Mechanisms) approach to the user interface design. The ROMC approach emphasizes that a focus for DSS design is providing users with familiar representations (graphs, plots, maps, charts, etc.) to communicate some aspect of the decision to other persons and that several types of memory aids should be provided to extend the users' limited memory.

(4) The findings of cognitive scientists provided a theoretical basis for developing a theory to explain the role and performances of graph and tables in decision making.

To discuss specific findings in the literature of a psychological decision theory, Einhorn and Hogarth (1981) decomposed the processes of judgement and choice into the subprocesses of information acquisition (information search and storage), evaluation, action, and feedback/learning and discussed several issues related to each subprocess. In regard to evaluating a set of alternatives, Einhorn and Hogarth discussed the need for finding principles underlying choice processes including a possibility of an overriding cost/benefit analysis, which may induce suboptimal behavior in some circumstances. Behavioral decision theorists proposed a variety of mechanisms that influence strategy selection. Of these, the cost-benefit framework of Payne (1976) and his colleagues provided a basis for DSS researchers for understanding the behavior of decision makers using DSS as to the selection of their strategy and the relationship between the use of DSS and decision quality.

The Impact of Cognitive Science on Model Management

Factor 3 appears to represent Model Management. Since 1975, model management has been researched to encompass several central topics such as model base structure and representation, model base processing, and application of artificial intelligence to model

integration, construction, and interpretation. Readers are referred to (Eom 1996) for a brief review of the literature on model management.

A group of DSS researchers (Loy 1991; Pracht 1986; Pracht and Courtney 1988) have investigated the use of an interactive graphics-based problem-structuring aid such as the Graphical Interactive Structural Modeling Option (GISMO) to support the problem structuring phase, which is the first stage of decision making processes of intelligence [problem formulation], design, and choice. In this line of research toward building an interactive graphics-based problem-structuring aid such as the GISMO, several contributing disciplines (cognitive psychology, imagery theory, dual coding theory, structured modeling, and a theory of problem solving) have made important contributions in investigating the relationship between the effectiveness of problem structuring and an individual's general thinking skills. Using GISMO, Loy (19[35]) found that the user's ability to create and use visual images is positively related to better problem-solving and problem-structuring performance. His findings imply that further DSS research is necessary to develop DSS tools which can provide effective support for decision makers who do not possess highly developed visual thinking skills.

Conclusion

The DSS area has undergone profound structural changes in the intellectual structure over the past five years (1991-1995). The result of the current study indicates that several DSS research fields/contributing disciplines are emerging (design, implementation, and cognitive science). Two subareas of DSS research are disappearing-- individual difference and foundations. GDSS research has been strengthened and model management research has been a continuously central research theme. Organization science and multiple criteria decision making are steady fields of DSS contributing disciplines. We have highlighted several contributions of cognitive science to the intellectual development of model management and user interface management areas.

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