COGNITIVE STYLE

AND

INFORMATION SYSTEMS DESIGN

by

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ABSTRACT

This paper discusses the results of a series of experimental studies related to cognition and information systems design. These studies (Vasarhelyi, 1983; Mock and Vasarhelyi, 1933; Mock et al. 1972; Mock and Driver, 1975) described in detail elsewhere are part a major experimental effort performed over 10 years, 4 settings and more than 15 experimental versions.

The common theme of examination of evidence in this paper is the effect of cognitive style vis-a-vis MIS design. Methodological discussion involves the use of the laboratory method in MIS research as well as subject, task and system surrogation.

The conclusions indicate the adequacy of the laboratory methodology for MIS design research issues provided the limitations of the method are considered. Its main features are unobtrusiveness in execution and facility of experimentation. Results indicate the potential of cognitive style as a design variable, the value of budget and variance information, the value of timeliness of information and significant differentials in information type and aggregation preferences.

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I. INTRODUCTION

The evolution of computer technologies has resulted in less expensive, more modular and more flexible data processing systems. These systems tend to be developed in-house and tailored to the corporate organizational structure.

Increased comprehension of common decision patterns among individuals of similar cognitive style, in conjunction with the above mentioned developments in computer technology, makes possible the tailoring of information systems not only to organizational structure but also to the individual making decisions. Mock et al. (1972) state that "...further research is needed to develop a taxonomy of relevant decision-maker characteristics which can be used to design more individualized information systems." (p.147)

Increased attention has been given in the literature to the usage of "decision aids" (Benbasat Dexter, 1982) which use operations research (OR) based techniques to supplement human decision making. Questions have been raised on the effectiveness of such systems in relation to differential human information processing capabilities. Some results seem to indicate definite patterns among different cognitive styles for the usage of these decision aids. A more elementary form of decision aid does not encompass a special OR based technique but simply selects particular information structures as more appropriate for particular decision makers. The basic research necessary for such an endeavor is discussed in this paper.

This paper presents some basic axioms related to human information processing that are relevant to MIS design issues. It discusses evidence from previous research on these axioms and on their implication for information system design. Concludes by proposing additional research and drawing conclusions on practical MIS design issues.

II. RESEARCH QUESTIONS

The AAA Committee on Human Information Processing (1973) divided human information processing research into four areas: (1) the Bayesian approach, (2) the Lens model approach, (3) the cognitive complexity/cognitive style approach and (4) the process tracing approach. The last approach is more a technique than a research approach per se. This classification, of value for basic HIPS research on the modeling of human decision processes is of limited value for practical MIS design issues. This paper draws on some of these findings to propose some MIS design axioms.

The MIS literature has started to show some interest on cognitive style design based issues. The initial efforts must attempt to classify decision makers that will use MISs into some sort of general categories. One approach to this classification

is the usage of general psychological typologies denominated cognitive style. Many cognitive style classification schemes exist.

Taggard and Robey (1979, p.31) state that " ....we see that no instruments have become " standard " in management research which investigates human information processing." In consequence, several theories of cognitive styled decision making exist that, given a set of often contradictory and heterogeneous findings, comprise the current body of knowledge (see Libby and Lewis, 1977, 1982 and AAA, 1973 for a survey of the literature). Within this context, only a tentative theoretical construct can be postulated. The construct which follows is an attempt to integrate conflicting literature findings, and incorporates a series of logically derived theoretical linkages. Its main purpose is to provide a framework for the testing of specific propositions.

A Theoretical Construct

A.1 Individuals are essentially different from one another, as the number of variables involved in personality determination is quite large. These variables also can assume a wide range of continuous values leading to an infinite number of permutations.

A.2 Within a business decision context, the number of variables of importance and the range of values they may assume is more limited. Axioms 1 and 2 lead to the conclusion that models of individual behavior will be in essence substantial simplifications of actual human behavior.

A.3 Cognitive style theory uses a discrete and rather small number of variables (with a very limited number of values) to explain the essence of management decisions. A theoretical framework and key variables are used as group membership determinants. For example, the AH (analytic x heuristic) framework is based on a theoretical Jungian (see Huysman, 1983) construct and examines patterns of decision making as group determining variables. On the other hand, the Driver framework (Driver and Mock, 1975) uses information utilization and objective focus as a way to classify individuals into groups.

A.4 Cognitive styles do not ultimately affect overall managerial performance and outcome. In situations where the objective function is unambiguous, there is a single stated objective and multiple performance determinant variables, individuals will perform similarly despite different cognitive styles. This ultimately performance balancing is due to compensatory behavior.

A.5 Individuals are versatile and will complement their weaknesses with additional inputs and accomplishments in the area of their strength. These effects will be reflected by time dedicated to tasks, information searched or used, communication

patterns, human information processing, filtering, etc. (see Vasarhelyi, 1977; Vasarhelyi, 1981). In general terms if

$$P = f(a,b,c,d,...)$$

where P is performance along a single clearly stated objective and a, b, c ... etc are several performance determinant variables. This axiom states that

$$P = P' = P''$$

where P, P' and P" are ultimate performances of individuals in different cognitive style groups. The performance determinant parameters may be drawn from previous research studies which identified or searched for differences along several variables between different cognitive style taxonomies.

Some variables that were examined in previous studies are: (1) type of information used (Vasarhelyi, 1977), (2) time taken to make decisions (Mock, 1968; Mock et al, 1972), (3) number of alternatives considered in the decision process (Driver and Mock, 1975), (4) need for timely information (Mock, 1969), (5) format and aggregation of information (Ronen, 1971; Tiessen, 1976), (6) comfort with the context (Vasarhelyi, 1977), (7) motivation (Zedeck, 1977), and (8) perceived effort.

Modeling the human decision process using cognitive style taxonomies is a simplification. In consequence statistical results are expected to be low and to explain only part of variances. With the evolution of research in this area more detailed taxonomies will come into existence and these statistical results improved. This state-of-the-art can be contrasted with some of the Bayesian and Lens studies (see Libby and Lewis, 1981) where statistical results tend to present much higher levels of variance explanation.

Parts of the above theory are to be used in the ensuing sections of this paper. The first consideration is the cognitive style framework to be used and its operationalization.

Cognitive Style Measurement

The AH framework is commonly used in the cognitive style-HIPS literature. (Huysman, 1968; Mock et al. 1972; Dickson et al. 1977) The pitcher and the coin test used by Huysman, the self evaluation questionnaire used by Vasarhelyi (1973) and the cognitive style instrument used in the Minnesota experiments (Dickson et al. 1977) have been compared to the Meyers-Briggs (1962) indicator and among themselves by Vasarhelyi (1973) and Zmud (1977) showing in most instances low but significant correlation. These are operational tests and likely to measure somewhat different constructs.

Another popular framework is the field independence (Witkins et. al., 1962) concept. It presents similar features as the AH framework and classifies individuals as "low analytics" or "high analytics". (Lusk, 1973; Benbasat Dexter, 1979; Otley Dias, 1982).

Driver and Mock (1975) based their study on a classification where Ss were classified along two dimensions: information use and decision focus. This led to five subject categories(decision styles). This categorization was used in several of the experiments discussed in this paper.

In conclusion, cognitive style taxonomies tend to be designed and implemented with cognitive psychological concerns in mind. Therefore they are not specifically fit for information and MIS studies. In consequence it is not surprising that results are usually weak in statistical terms. There is real need for psychometric studies oriented towards typologies of people along the information usage and human information processing dimensions. Factor analysis of large human information banks as the one generated by these studies may provide such an empirically based classification.

Tailored Systems

Although one might not expect improvements in "pure performance" by decision makers, tailoring of information systems may serve to improve the overall decision outcome or to change the cost/benefit tradeoffs in the decision process. In consequence, systems may be tailored to support and enhance human decision maker performance. Among the several variables earlier mentioned as used in the HIPS/cognitive style literature, two will be manipulated in this study: aggregation and type of information. These will be used as parameters in information systems design and related to decision maker cognitive style.

Information and Performance

Differential performance by subjects will be affected by compensating behavior, over the experimental period, for their information processing weaknesses and/or use their processing strengths.

One typical difficulty faced by many studies is the low natural relationships between task and performance. This relationship is often referred to as "diagnosticity". For example good analysis of financial statements will not necessarily lead to superior stock choice. (Vasarhelyi, 1983)

Research Questions

The emphasis of this discussion is on whether subjects of different cognitive style request different types of information and if they process what they receive.

The basic research questions being addressed relate to the potential of information system tailoring to different cognitively styled individuals.

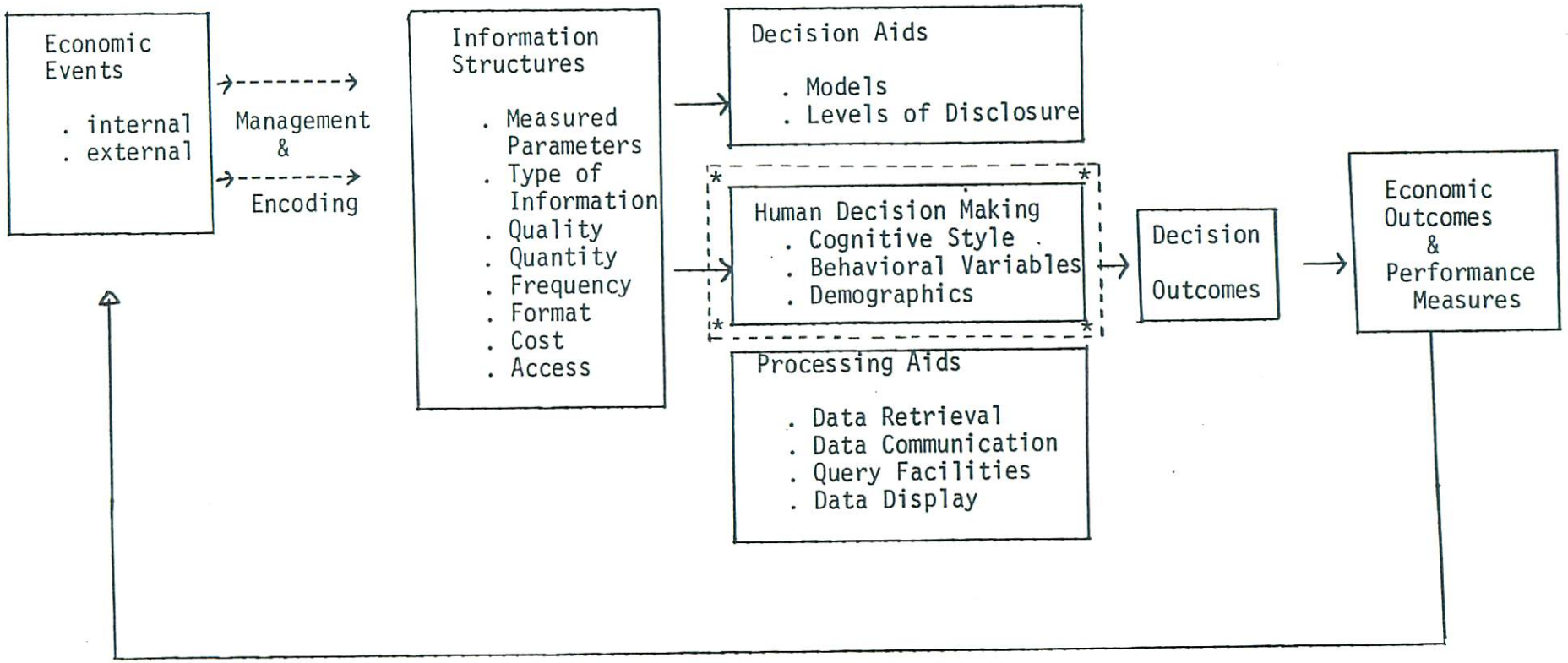
1. Is cognitive style a relevant information system design variable?

2. Can these tailored systems improve the cost vs. benefit balance of decision support?

Figure 1 displays a succinct model of human information processing and information design variables. Some of these postulated relationships are examined in greater detail later in this paper. Most of the relationships however, require substantial additional research even for an elementary level of comprehension.

Figure 1

Human Information Processing
and
Information Design



* Filtering factors on human information processing: channel capacity, perception bias, anchoring, memory retention factors, associativity, verbal and/or pictorial recognition, pattern selection/recognition and programmed heuristics.

III. METHODOLOGY

Laboratory studies were used as the vehicle to discuss the issues above. Field studies and some archival methodologies may be used at later stages of this line of research but the laboratory method is essential in this early phase.

A series of different decision settings such as a production management game (Dickson et al., 1977; Lusk, 1979), a macroeconomic game (Mock, 1968) have been used in similar contexts in other research studies

Selected Studies

An overview of previous studies is presented in this section to facilitate an understanding of longitudinal aspects of the research, to help demonstrate some of the methodological difficulties and enhancements that have occurred, and most importantly, to present some new interpretations of previous results from the standpoint of human information processing. Within the span of the research, four major types of experimental settings (decision contexts) have been used. In each case, a business or economic decision model has been incorporated within a controlled experiment. Table 1 summarizes the methodological differences within each decision context.

The Experimental Settings

Five versions of the Information Structure experiments (denoted IS1, IS2,...) have been conducted. The IS setting is unique in its emphasis on controlled information differences and in the underlying structure that may be optimized. Complete description and documentation for these experiments can be found in Mock (1969) and Mock and Goodfried (1975).

The second decision setting involves a more intricate forecasting problem and a more complex information and decision support system denoted as the Interactive Planning System (IPS). Rather than researching specific information differences, the IPS experiments emphasized the combined effects of cognitive style (specifically analytic versus heuristic decision approaches) and type and amount of information utilization. A more complete description of IPS may be found in Vasarhelyi (1973).

The third decision context utilizes a Simulated Stock Exchange (SX) which has been run under three specifications (SX1, SX2 and SX3). The cross-contextual research results reported in Mock and Vasarhelyi (1983) involve IS4 and SX1. Like the IPS methodology, the stock market simulation emphasizes information utilization and cognitive style differences. But unlike IPS, normative decision models such as portfolio models may be referenced to evaluate performance differences.

The fourth decision context utilizes the Accounting Data Analyzer (ADA) which entails an interactive portfolio choice decision using a three stock context. This version of a stock market setting (where a maximum exists) is highly structured and monitorable. Automatic traces of information addressed and utilization times are gathered and allow for a simplified version of process tracing. The ADA experiments, unlike their precedents, used a cognitive style and information structure matching design whereby subjects were given cognitive style tailored information systems. These "tailored" systems supply users with their "preferred" levels of data aggregation and information type. Subjects were also given, on a random basis, "counter-prescriptive" systems that were tailored for the preference of the opposing cognitive style.

Each experiment in Table 1 has dealt in some way with cognitive style. The distinction between decision approach (analytic versus heuristic) and decision style (decisive, flexible, hierarchic, and integrative) lies in the complexity of the underlying behavioral models. Part of the needed research involves an evaluation of various cognitive style models and measurement tools.

See Mock, Estrin, and Vasarhelyi [1972].
See Driver and Mock [1975].

TABLE 1

CLASSIFICATION OF EXPERIMENTAL SETTINGS (DECISION CONTEXTS)
FOR THE ACCOUNTING SIMULATION EXPERIMENTS

	Methodological Differences			
Experiment Name	Decision Setting and Rule (α)	Information System (η)	Information Utilization (ρ)	Behavioral Factors (B)
Information Structure (IS) Experiments	Highly Structured Micro-economic game, Optimizable	Controlled Differences (Timeliness, Coarseness, Completeness)	Specific Information Processing Rules Tested	Decision Approach, Decision Style
Interactive Planning System (IPS)	Unstructured Financial Planning Case, Not Optimizable	Single Structured Planning System	Measures of Type, Amount of Information Used	Decision Approach
Simulated Stock Exchange (SX) Experiments	Capital Stock Market, Theoretical Decision Models (i.e. Portfolio Theory)	Not Controlled	Measures of Type, Amount of Information Used	Decision Approach, Decision Style
Accounting Data Analyzer (ADA)	Structured Stock Selection Setting, Optimum Available	Prescriptive, Counter-Prescrip. or Neutral	Information Usage Training, Times and Decisions	Decision Approach

Summary of Previous Findings

Table 2 summarizes the main results of the four major types of experimental efforts. Overall, cognitive style/decision style has consistently shown weak but significant differential effects over a series of variables and settings. MIS designers should note the laboratory examination of issues such as: information timing (Mock, 1969); budget setting (Mock, 1973, Mock and Vasarhelyi, 1977); leasing patterns (Mock et. al. 1972); information type (Mock and Vasarhelyi, 1983); cognitive style tailoring (Vasarhelyi, 1983) and attitude changes (Vasarhelyi, 1981).

TABLE 2

SUMMARY OF MAJOR EXPERIMENTAL INFORMATION PROCESSING FINDINGS

Experimental Variables	EXPERIMENTS						
	IS1 Mock 1969	IS2 Mock 1973	IPS Vasarhelyi 1973	IS3 Driver & Mock 1975	SX1 and IS4 1976	SX2 and SX3 1979--80	ADA 1981
Cognitive Style - Decision Approach	---	---	Significant Differences in Information Utilization (Quantity)	---	Significant (Pre-Test) Differences Information Type and Quantity Preferences	Regression Modeling of Decisions made across Cognitive Style	Differences in Information Preferences - Aggregation - Type
Cognitive Style - Decision Style	---	---	---	Significant Decision Speed Effects	Significant (Pre-Test) Differences Information Type and Quantity Preferences	Significant Pre-Post Attitude Change	---
	Optimal Information Processing Rules Significant	Optimal Information Processing Rules Not Significant	Miller's Hypothesis Supported	---	Optimal Information Processing Rules Significant but Individual Differences Dominant	Relationships Between Decision Approach and Decision Style	---
Primary Focus of Experiment and/or Analysis	Methodology, Value of Timely Information	Value of Budget Information	Decision Support System, Information Utilization	Decision Style Theory, Accounting Feedback	Cross-Contextual Methodology, Cognitive Style, Information Value	Cognitive Style Information Utilization	Cognitive Style Tailoring of Information Systems

Information Structures

Typical of experimental studies is the comparison of alternative information structures. Methodologically, alternate information structures require some assumptions on decision maker information models to assess the information content and value of cues provided. These are mostly subjective and make experimental control extremely difficult. The tradeoffs between controllability and result generalizability are non-trivial. Our early results show an emphasis on basic research while more recent studies allowed for more realistic tasks at the expense of experimental control.

Information Cost

Information is not a free good and often in experimental contexts its cost is neglected. Valid experimentation must consider this difficulty and deal with it accordingly. Attributive cost to information (Pankoff Virgil, 1970; Vasarhelyi, 1933) is also a non trivial task. The realistic assessment of data processing, retrieval and support costs for a fictitious laboratory setting is nearly impossible. This difficulty is compounded by the need of a realistic payoff/cost relationship to evaluate subject performance.

Laboratory Decision Support Systems

Table 3 displays the key features of the softwares used in the experiments. All systems were interactive and allowed direct user interface except for the early versions of IS. IPS and ADA had its over databases for user access. IS used arbitrarily at environmental parameters.

Table 3

Laboratory Software Features

Attribute / Equipment	Unobtrusive Software Based Decision Traces	Programming Language	Hardware Support	Information Usage Costs	Type of Information* Provided	Mode of Interaction **	Nature of Software
IS	NO	LCL APL	PDP-11 IBM 360/91 370/158	NO	Qt	Q&A	Algorithm Calculator
IPS	YES	APL	IBM 360/91 DEC 2060	NO	Qt Qn	D	Planning MIS Emulation
SX	NO	APL BASIC	DEC 2060 PDP-11 DEC 2060 IBM 370/158	NO	NA	Q&A	Portfolio Tracking System
ADA	YES	BASIC	DEC 2060	YES	Qt Qn	M	Decision Tracking System With Data

* Qt - Quantitative, Qn - Qualitative

** Q&A - Question & Answer; D - Direct Path; M - Menu Selection

Measurement Instruments

A bio-data form and unobtrusive traces were administered through the ADA system obtaining background, feature utilization and decision time data. Traces were performed by the computer which recorded all data and software features utilized as well as the time dedicated to each display used. A debriefing questionnaire was administered at the end of the experiment. The AH instrument was part of the bio-data questionnaire and triggered the information structure selection.

SELECTED EXPERIMENTAL RESULTS

The IS Experiments

The IS experiments were performed in four versions which examined:

(1) Information timeliness (online vs delayed information)
(2) Learning patterns vis-a-vis cognitive style
(3) Decision style
(4) Value of budget information and budget variance information

Mock (1969) found substantial differences between online and delayed information. Indicating the feasibility, in laboratory conditions, of evaluating timely versus non-timely information. The same set of experiments (Mock et.al., 1972) also showed differential learning patterns and model building behavior between analytic and heuristic decision makers. Another IS experiment (Driver and Mock, 1975) also indicated differential behaviors among different decision styles.

Two additional experiments (Mock 1973a; Vasarhelyi and Mock, 1977) found effects of intensive decision improvement due to budget information and significant effects of supplying variance feedback.

IPS Experiment

The usage of a less structured planning context (Vasarhelyi, 1977) allowed the examination of decision style, type of information (qualitative vs quantitative), information system user perceptions and issues in information overload. Its results showed some cognitive style effects, attitude changes, information overload and decision speed effects.

Unlike the IS experiments the IPS does not have an optimal for comparison purposes. Therefore, judges were used for performance evaluation.

SMS Experiment

The SMS experiments (Vasarhelyi, 1981; Mock and Vasarhelyi, 1983) examined data utilization perceptions, cognitive style, decision approach and regression based decision modeling. The results indicated substantial perception changes, weak but observable cognitive style effects and inconclusive regression results.

Overall, the SMS experiments presented good cross-experimental validity (similar results between SMS1, SMS2 and SMS3) and reasonable cross-contextual (compared with the IS experiment). The SMS experiments highlighted the difficulties with contexts of low diagnosticity and pointed further to the need for additional analysis for the effect of context on research results.

Cognitive Style Tailoring Effects

This experiment examined the tailoring of information systems to cognitive style using the AH framework. In addition it attributed information usage costs to terminal linkup time and information accesses. Traces were kept for all man-machine interaction allowing careful interpretation of decision times and type of information accessed.

The results indicated initial performance differences accompanied by adaptive behavior leading to homogeneous subject performance at the last decision period. This indicates differential learning patterns such as found in Mock et al (1972). Decision makers developed substantially different strategies (reflected by performance data).

On the other hand, the result seemed to indicate prescriptive mode (information system designed for the user's cognitive style) users to be more interested and comfortable with the information being supplied.

Close examination of the data seems to indicate some interaction between the factors cognitive style and information structure.

CONCLUSIONS

This paper examined a series of experimental information studies designed to evaluated information system features and human usage of these systems. The particular emphasis of the studies laid on cognitive style and information characteristics. A theoretical construct of human information processing was used for the generation of research questions.

The methodology seemed promising in terms of close monitoring of decision processes without obtrusion or manual analysis of lengthy protocols. This methodology also allows for larger samples to be considered as a variation of standard process tracing in protocol analysis (e.g. Biggs and Mock, 1980). Another methodological consideration is the preferability of the unobtrusive experimentation in laboratory settings instead of the obtrusive experimentation in real corporate MISs. The classical tradeoffs of generalizability against control also prevail.

Overall, the experimental results seem to be strong and based on a long series of experiments using different contexts and research questions. On the other hand, as expectable (Mock and Vasarhelyi, 1983), specific hypothesis tests and explanatory statistics are weak for most tests.

MIS designers may draw a few tentative conclusions from these results: (1) real time systems have incremental information value to decision makers, (2) different types of individuals will present substantially different learning patterns, (3) definite preferences concerning types (qualitative vs. quantitative) of information will emerge among cognitive styles, (4) aggregation of information will also be a definite design concern related to cognitive style, (5) decision context will also affect the design of the most desirable information structure.

These basic information research questions should now be related to specific issues related to MIS design and information technology in the 80s. For example the advent of easy computer based communication among managers, the potential for distributed computing, the possibility of distributed databases, the changes in the cost x benefits of data storage and retrieval media are all potential issues for laboratory exploration.

In addition, the results are interesting enough to warrant further extension and exploration. A series of variables such as mode of presentation, timeliness of information and information content may be introduced to expand the scope of these studies. Further experimentation, along the lines of a more complete experimental designs, may allow for a more in depth data analysis and for stronger potential conclusions about the desirability of cognitive style tailoring of information systems.

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