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Glenn J. Browne
University of Maryland

Ramesh V.
University of Maryland

Mitzi G. Pitts
University of Maryland

Michael B. Rogich
University of Maryland

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Glenn J. Browne, V. Ramesh, Mitzi G. Pitts, Michael B. Rogich
Department of Information Systems
University of Maryland, Baltimore, MD 21250

I. Introduction

The representation of user requirements is a crucial aspect of the systems analysis process. The quality of implementation models used to build a system, and of the ultimate system itself, are dependent largely on the extent to which systems analysis models faithfully represent users' requirements (Jarvenpaa and Machesky, 1989). Further, the need for users to validate requirements documents necessitates systems analysis models that communicate requirements clearly and effectively (Larsen and Naumann, 1992). Modeling devices may be more or less formal, and the degree of formality has implications for user understanding (Fraser, Kumar, and Vaishnavi, 1991, 1994). However, there have been no empirical tests of the degree of formality that is optimal in systems analysis models. The present research seeks to help fill this gap by providing an empirical test of various representational devices.

The requirements determination phase of systems analysis consists of two major functions: the elicitation of information and the representation of that information (Browne, 1996; see Davis, 1982, and Fraser et al., 1991, for similar ways of organizing requirements determination). Of interest in the current research is the representation of information. Representations are the external manifestation of the user's conceptualization of the application environment (Srinivasan and Te'eni, 1995). They serve as the medium of communication between the analyst and user, allowing the user to determine whether the analyst has accurately and completely specified the requirements the user has evoked. However, representational devices can function as such a medium only if the devices are easily understood by both users and analysts. Unfortunately, the formality of existing representational tools suggests that they were developed to facilitate the communication between analysts and system builders rather than between analysts and users (Fraser et al., 1991). Development of principled *informal* tools for representing user requirements presents an opportunity for improving the requirements determination process.

Although less formal representational forms have been proposed (e.g., Browne, 1996; Montazemi and Conrath, 1986), there have been no empirical tests of whether users better understand more formal or less formal tools. As noted, an understanding of the external representations of the proposed system is critical to both a faithful transfer of knowledge from user to analyst and a meaningful "sign-off" on requirements documents by users. Determining a baseline for what end-users can effectively and efficiently understand is important for both systems analysis theory and practice. Therefore, the basic research questions addressed in the present study are: (1) Whether more formal requirements specification devices such as entity-relationship diagrams communicate requirements more effectively to users, or whether users better understand less formal representational devices; and (2) How should less formal devices be constructed and evaluated to maximize the effectiveness and efficiency of communication between analysts and users?

II. Background

Formal and Informal Tools for Representing Requirements

A variety of methods have been developed to help structure the systems analysis and design process and to communicate system requirements. The methods vary in terms of their degree of formality. For example, Dart et al. (1987) classified methods as "informal," "semiformal," or "formal" (see also Fraser et al., 1994). Informal methods are those that do not have complete sets of rules that regulate the types of representations that can be created. Examples of these methods include natural language text and informal pictures or diagrams. Semiformal methods have specified rules for creating the representations. Examples include data-flow diagrams (DFDs) and entity-relationship diagrams (ERDs). Formal methods are those with a mathematical foundation and rigorously-specified syntax. Examples include petri nets and executable specifications (see also Denning, 1991).

Using this classification, only informal and semiformal methods are relevant for systems analysis. Semiformal diagrams can be used to develop implementation-oriented models that guide system builders in the construction of applications. However, these diagrams may be difficult to use in the communication process between analysts and users (Lohse, Min, and Olson, 1995). For example, Fraser et al. (1994) state that "The very formality which makes formal specifications desirable during the later phases of requirements specification makes them an inappropriate tool for communicating with the end user during the earlier requirements elicitation and confirmation stages" (p. 75). Larsen and Naumann (1992) note that easily understood and verifiable representations are not useful for system construction, and representations with enough detail, precision, and rigor for building systems are not likely to be understandable to users. Despite these concerns, the predominant methods recommended by systems analysis and design texts for representing user requirements are semiformal methods (e.g., Whitten, Bentley, and Barlow, 1994). However, techniques used in practice often include informal methods (Fraser et al., 1991; Fuggetta et al., 1993), despite the fact that there is little guidance for the analyst in the use of such methods.

Guidelines for Developing Informal Tools

To test whether informal tools are more effective in the communication process between analysts and users, two important issues are relevant. First, what informal tools exist that are used or have been proposed for systems analysis? Second, how should such tools be developed and/or evaluated? Existing informal tools appear somewhat limited. Narrative text is often used to describe system requirements (Fuggetta et al., 1993; others), as are simple diagrams and flow charts (Fraser et al., 1991). Other graphical techniques, many borrowed from other disciplines, have also been proposed (e.g., Browne, 1996; Montazemi and Conrath, 1986). However, there is little evidence that systems analysts are trained in the use of informal techniques. Further, there have been no empirical studies reporting on the use or effectiveness of such tools.

Yadav et al. (1988) propose that systems analysis techniques should be evaluated according to syntactic, semantic, communicating ability, and usability dimensions. We contend that comprehension by and communication with users should be the focus of informal modeling techniques, as that is what makes them usable. "Syntax" in informal models may be defined as how well the model reflects natural principles of human perception and cognition. The precision afforded by highly-structured, mathematically-sound syntax is more suitable for the communication between systems analysts and builders.

The syntax aspects of representational devices concern basic principles of perceptual and cognitive psychology (Lohse, Min, and Olson, 1995). A number of guidelines have been proposed for improving perceptual and cognitive considerations. For instance, Lohse et al. (1995) point out that semiformal tools such as DFDs do not conform to some simple axioms of human perception. For example, people in western cultures read diagrams from left to right and from top to bottom, just as they read text. Empirical evidence has shown that when diagrams are not arranged following these principles, significant biases in the interpretation of the diagrams emerge (Guri-Rozenblit, 1989; Winn, 1993). DFDs and ERDs do not follow these perceptual conventions.

Similarly, Winn (1993) offers a variety of empirical evidence concerning people's search for information in diagrams that should be accounted for in informal modeling tools. Perceptual processes such as discrimination of objects and grouping of symbols guide users in their initial understanding of diagrams (Treisman, 1982). Hence, for example, the clarity and differentiation of symbols is an important factor in understanding diagrams (this is similar to the "visual salience" notion of Jarvenpaa and Machesky, 1989). Cognitively, users' knowledge of the symbol system being used is an important criterion in understanding. For instance, hierarchies, flow diagrams, and matrices have been shown to be symbol systems that people generally understand and are able to follow in predictable ways (Winn, 1993).

In sum, modeling tools such as DFDs and ERDs are not constructed to take advantage of human perceptual and cognitive inclinations, and hence it can be argued that their syntax is less than optimal. Whether their syntax prevents user understanding is an empirical question that is investigated in the present research. Informal tools developed as alternatives to semiformal methods should be designed with communication and usability in mind, accounting for human information processing capabilities and limitations.

Hypothesis

In light of the above discussion, the following hypothesis, stated in the alternative form, will be tested in the present study:

Users will understand information requirements represented using informal representational devices better than they will requirements represented using semiformal representational devices.

III. Method

Two groups of users will be recruited for the experiment. One group will consist of students from university classes, and represent subjects with only minimal understanding of the purposes of representational devices and the nature of user requirements for information systems development. A second group will be recruited from users of information systems at a major corporation. This group of subjects will have experience with various software packages and be familiar with the nature of user requirements. This design will test the effects of different representational devices on relatively naive and relatively sophisticated users.

Two business scenarios will be created, each of which contains explicit requirements for an information system application. For each scenario, a systems analyst expert in modeling techniques will create an E/R diagram reflecting the stated information requirements. These diagrams will be verified by a second expert analyst. Informal representational tools for each scenario will also be created by the analysts.

As noted, each scenario will include a list of information requirements for the system. However, the list given to subjects will not be a complete list of the requirements specified in the diagrams. The subjects' task will be to determine whether the list of requirements is correct. That is, subjects will decide which of the requirements are present or missing in the list, and which are presented incorrectly in the list. A worksheet will be given to each subject to facilitate the comparison between the list and the diagram.

Subjects in each group will be given a packet containing training materials, examples, and the experimental tasks. The training materials will consist of minimal training in the notation used in the diagrams. Examples will then be given to illustrate the use of the notation. The training is intended to simulate the kind of systems knowledge that most users might have in business environments. Subjects will read through the training materials and examples, and then perform the experimental tasks.

Each subject within each group will perform two tasks. A given subject will first receive one business scenario represented using either an E/R diagram or the informal tool created for the current research. The same subject will then receive the other business scenario presented using the tool not used with the first scenario. The two scenarios and two tools will be matched in a balanced fashion within groups, and presentation order of the scenario/tool combinations will also be balanced.

To measure the relative effectiveness of the formal and informal representational tools, subjects' worksheets will be analyzed and the number of correct requirements identified, the number of missing requirements identified, and the number of requirements identified as incorrectly stated will be counted.

A two-way mixed-design analysis of variance will be employed to test the results of the treatments. Tests will be performed on group (between subjects) and representational device (within subjects). Of primary interest are differences between the representational devices; of secondary interest are differences between more knowledgeable and less knowledgeable users.

References available upon request from first author.