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December 2007

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REQUIREMENTS ELICITATION TECHNIQUE SELECTION: A THEORY-BASED CONTINGENCY MODEL

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Abstract

Requirements elicitation has been recognized as a critical stage in system development projects, yet current models prescribing particular elicitation techniques are still limited in their development and application. This research reviews efforts aimed at addressing this, and synthesizes a common structure consisting of project contingencies, elicitation techniques, logic of fit, and a success construct, arguing for the need to more comprehensively study and organize each. As a first step in this research, models drawn from organizational literature are used to categorize project contingencies into dimensions dealing with their impact on the uncertainty and equivocality of the overall development project.

Keywords: requirements determination, elicitation techniques, uncertainty, equivocality, contingency.

Introduction

Information requirements determination (IRD) has long been considered a critical stage in system development projects (Browne and Ramesh, 2002). Advancing our understanding in this area can be argued from four different perspectives. First, requirements determination is conducted early in the systems development lifecycle, and outcomes of this phase have a strong impact on project quality and performance. In addition, strong empirical evidence highlights the negative effects requirements uncertainty (Nidumolu, 1995) or requirements risk (Wallace, et al., 2004) have on development project performance. Third, issues related to requirements determination consistently top rankings of software development risks as perceived by project managers (Schmidt, et al., 2001). Finally, lack of understanding about users´ needs and expectations results in the failure of a significant proportion of development projects (Hickey and Davis, 2003). In summary, any improvement in the process of eliciting and understanding requirements holds significant promise for the improvement of development activities (Browne and Rogich, 2001).

Despite the importance for development success, and the significant amount of research studying the relative effectiveness of different elicitation techniques, the literature has yet to converge on a framework prescribing the most effective use of specific techniques in varying situations; although several have been proposed (Davis, 1982; Hickey and Davis, 2004; Tsumaki and Tamai, 2005). More than twenty years ago, Valusek and Fryback (1985) stated "... *we should soon be able to prescribe a strategy and tool for managing through the IRD portion of these problems…*" yet progress in this regard has been scant. While significant research has been conducted on the performance effects of specific elicitation techniques, we are no closer to prescription than before.

This work seeks to establish the foundations of a research program into the selection of requirements elicitation techniques. It does so by building on the contingency structure proposed by Hickey and Davis (2004), providing the underlying logic, grounded on the information processing model proposed by Daft and Lengel (1986), for the increased effectiveness resulting from appropriately matching[1] elicitation techniques to project situations. The task for which the system is developed, users, stakeholders, and analysts, are characterized as sources of uncertainty and equivocality, and elicitation techniques as mechanisms with the capacity to reduce and resolve same. This framework offers a more detailed perspective by moving away from overall project levels of uncertainty and equivocality, and into the task, users and analysts, each with their own particular issues, as separate sources, potentially requiring different techniques for successful elicitation performance.

Literature Review

Most models of the IRD process distinguish between three different groups of activities: *elicitation, specification*, and *validation* (Browne and Ramesh, 2002). In the elicitation phase, functional requirements for the proposed system are obtained from all relevant users of the new application as well as interested stakeholders. This information can be obtained in a variety of ways and the selection of the most appropriate one, given project characteristics, is the main interest herein.

Elicited requirements form the input to the specification stage, in which a variety of modeling and representational techniques are employed to formalize and document said requirements, including process logic, data structure, and system behavior. These representations are then used in verifying that obtained requirements are correct, involving the selection of a validation or assurance strategy (Naumann, et al., 1980). The final output of IRD is a set of system diagrams, agreed upon by all involved parties, which can then be implemented into a new application. Although generally depicted as proceeding in a linear fashion, these activities are highly iterative in nature. Of the three phases, requirements elicitation is the most time and resource intensive one (Hickey and Davis, 2004).

Past research on IRD can be grouped into two different categories: that related to a specific technique or method, and that modeling the selection of elicitation techniques in general (Hickey and Davis, 2004). The first group of studies are empirical in nature and investigate the applicability of different elicitation techniques, without considering the situation in which such techniques would be most appropriate. This line of research compares the elicitation performance of an advocated approach against some baseline methodology. Examples include Montezemi and Conrath (1986) (cognitive mapping techniques), Marakas and Elam (1998) (semantic structuring), Zmud, Anthony and Stair (1993) (mental imagery) or Rockart (1979) (critical success factors). A more comprehensive review can be found in Byrd, Cossick and Zmud (1992).

The second category includes a number of conceptual models attempting to describe the elicitation process and model technique selection for a given project situation. This research can be traced back to the seminal work of Davis (1982), who proposed different characteristics of the project, application, users, and analysts led to the formation of three process uncertainties: the existence and stability of a set of usable requirements, the ability of users to specify the requirements, and the ability of analysts to elicit and evaluate them. These process uncertainties in turn impacted an overall requirements process uncertainty. The level of this overall measure indicated which of the four elicitation strategies (asking, deriving, synthesizing or discovering) should be selected as a primary approach.

More recently, Hickey and Davis (2004) proposed a unified model of requirements elicitation that sought to improve on past conceptualizations by distinguishing between requirements already known and those remaining to be discovered, and among project situations (including characteristics of the problem domain, the solution domain, and the project). The authors developed a mathematical formulation of the model, where at each elicitation step, a technique is applied to the situation capturing some portion of the unknown requirements resulting in an improved state of knowledge about characteristics of the system under development.

While this model advanced the understanding of the elicitation process by clearly distinguishing and articulating the different components, it did not specify the underlying logic by which techniques should be matched to specific situations, nor did it provide organizing frameworks for the model components, limiting their research to examples of the elements found in each of them. This has also been a limitation of other models (e.g. Tsumaki and Tamai, 2005). While compatible with the Hickey and Davis (2004) model, this paper delves deeper into each portion of that framework.

[1] The use of the term *matching* herein is intended to convey a high level of fit between two concepts and does not represent an argument for a particular conceptualization of fit.

Research Model Development

The research model presented herein builds on a stream of literature applying contingency theory to specify the matching of particular techniques or methodologies to different project situations. Table 1 compares extant frameworks on their conceptualization of these components, as well as the logic employed to stipulate the fit between them. This paper draws upon the theoretical framework of information processing theory (Daft and Lengel, 1986) and synthesizes past research into the model depicted in Figure 1.

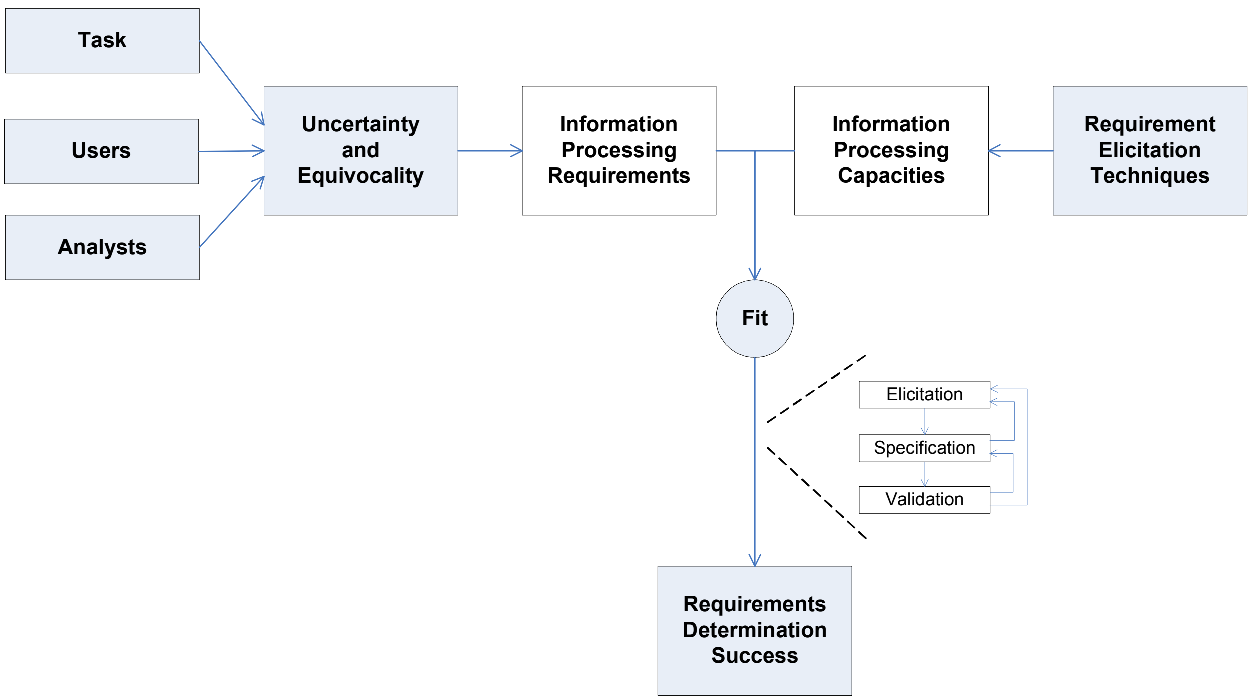

Figure 1. Proposed research model

The underlying assumption is that a first pass at a theory of requirements elicitation technique selection should be able to account for, organize, and relate at least four different components: the contingencies affecting the need for the elicitation process, the available techniques and their effects upon those contingencies, a logic of fit establishing the "why" behind matching techniques to contingencies, and a measure of requirements determination success to assess the performance effects of the matching described above (Premkumar, et al., 2003), and judge the degree to which the process has been completed and a new phase of the development lifecycle should begin. Each of these components is briefly described next, with the contingencies portion of the model being further developed, as the starting point of this research. Table 1 reviews and summarizes existing research in this area, categorized in terms of contingencies, techniques, and logic of fit. Requirements determination success, on the other hand, has not been explicitly discussed in the reviewed literature, and thus was not included in Table 1.

A Framework for Understanding Contingencies

Table 1 inventories a number of contingencies suggested as relevant to the selection of elicitation techniques. Some authors have attempted some degree of categorization of these contingencies, such as among the utilizing system, the application, users and analysts (Davis, 1982), or organization and project, customers and users, developers and analysts, and problem and solution domain (Hickey and Davis, 2004); in all cases, these efforts have been limited to grouping characteristics or examples around a common label (e.g. characteristics of users, of the utilizing system, of the analysts, etc.). However, an organizing framework, or a set of them, tying these lists of characteristics to their impact on the selection of techniques has not yet emerged.

This work applies models borrowed from the organizational literature to systematically understand the effects these issues have on uncertainty and equivocality, and thus on elicitation technique selection. Although some prior work was implicitly organized along those lines, this represents a first attempt to systematically apply information-processing theory to requirements elicitation technique selection. It should be noted many of the contingencies in the extant literature have not been included in the categorizations developed below: those concerning the proficiency of the analysts and developers, and those imposing constraints on the methodologies that could be employed. From a normative point of view, neither of these should influence the ideal pattern of alignment between contingencies and elicitation techniques.

Contingencies related to the task[2]

Characteristics of the task can be usefully conceptualized along the two dimensions of task variety and task analyzability (Daft and Macintosh, 1981). The first dimension relates to uncertainty and refers to the number of exceptions or novel events requiring different methods and procedures (Bensaou and Venkatraman, 1995). When task variety is low, little information is necessary to describe the new system. Conversely, high task variety requires a significant increase in the amount of information needed to fully describe the proposed system. Task analyzability, on the other hand, is closely tied to equivocality and depicts the extent to which there are known procedures specifying the sequence of steps to be performed in the completion of the task (Keller, 1994), affecting the extent to which activities can be structured in a routinized or systematized way (Van de Ven and Delbecq, 1974).

Another important distinction is between task-possessed (Chang and Tien, 2006) and non-possessed information prior to the start of the elicitation process. The characteristics of the task supported by the development project set an innate level of analyzability and variety needed to be addressed through appropriate gathering techniques. Prior research, however, has recognized the existence, in a variety of forms, of information about the task. These include past user and analyst experience (Davis, 1982; Hickey and Davis, 2004), or external sources such as documentation, knowledge bases, best practices, etc. (Tsumaki and Tamai, 2005). Further research is required to understand the extent to which the notion of task-possessed information may be a critical determinant suggesting the use of discovery (or experimental) elicitation methods.

Based on the discussion above, Table 2 groups proposed task-related contingencies (shown in Table 1) into three categories: those affecting task analyzability, those affecting task variety, and those affecting the nature and amount of task-possessed information. Ideally, the last category would also be split between factors influencing analyzability and variety, however, the very general expressions used to label these contingencies (e.g. user experience with the utilizing system) does not allow for such fine-grained distinctions at this stage.

Contingencies related to users and analysts

Past research has emphasized communication-related issues when dealing with contingencies about users, stakeholders and analysts, including the perspective developed by Guinan and Bostrom (1986); within, among and between communication obstacles (Byrd, et al., 1992; Valusek and Fryback, 1985); and other cognitive limitations (Browne and Ramesh, 2002; Davis, 1982). However, an examination of Table 1 reveals few of the contingencies proposed in the literature address these issues, but for diversity of user needs and willingness to reach consensus (Hickey and Davis, 2004) and those related to project size (see Table 2), under the general assumption larger projects involve more disagreement among users. To the extent information-processing limitations (Davis, 1982) are present, to a greater or lesser degree, in all human beings, it seems appropriate the design of elicitation techniques take these issues, such as cognitive biases, satisficing, and recall problems, into account (Browne and Ramesh, 2002).

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[2] Here *task* refers to the organizational task for which requirements are being gathered and a new system development proposed, and not to the task of developing the system itself.

This research, however, challenges the notion communication obstacles between users and analysts and among different user groups are always present during elicitation. Rather, it proposes these need to be understood, measured, and incorporated as part of the contingencies dictating the optimal choice of elicitation technique. This includes both their existence and likely impact on the development project. For instance, although differences in the nature and stability of perceptual frameworks between users and analysts (Valusek and Fryback, 1985) may well exist, they may not be a major problem in a project where the large majority of the requirements may be derived from existing systems in the current or other organizations, industry studies and benchmarks, etc. (e.g. the deriving approach, Davis, 1982).

Similarly, communication obstacles among different user groups would only arise when there is more than one homogeneous group of users involved in the development effort. Although simplistic, these type of distinctions have not been considered in extant literature. To the extent that group techniques, such as those described by Duggan (2003) or Coughlan and Macredie (2002), are successful in addressing many of these issues but, at the same time, very costly to execute (in terms of the resource commitments necessary, both human and financial), improving our understanding of the most appropriate opportunities for their application becomes an important objective of this research.

As far as the effects of these two communication obstacles on the proposed logic of fit, they appear to be most related to the notion of equivocality, particularly as it refers to the existence of multiple and conflicting interpretations about organizational situations (Daft and Lengel, 1986). Differentiation between departments, which results from the adaptation efforts of units to better satisfy the demands of their own tasks and environments, leads to disparities in time horizons, goals, values and priorities. Equivocality is resolved by the exchange of views among participants to define problems and enact shared interpretations of the situation (Daft and Lengel, 1986). This closely resembles the objectives of group techniques such as those discussed above.

Requirements Elicitation Techniques

As shown in Table 1, a wide variety of techniques have been proposed to deal with the project contingencies present in IRD. Extensive reviews of available techniques have been conducted by Taggart and Tharp (1977) and, more recently, by Byrd et al. (1992). The latter classified techniques according to communication obstacles (Valusek and Fryback, 1985) addressed by each (within, between, and among), problem domain categories emphasized, and locus of control of the elicitation process (analyst vs. user). Other researchers have attempted to construct an ontology of elicitation techniques by focusing on structural characteristics, such as physical and temporal co-location, analyst role, record-keeping, anonymity, stakeholder count, etc. (Hickey and Davis, 2003).

While useful for the purpose of describing different elicitation techniques, these frameworks are of limited value in distinguishing among them. For instance, of the eighteen techniques surveyed by Byrd et al., (1992), thirteen were classified as appropriate for addressing two or all three of the communication obstacles identified by Valusek and Fryback (1985). Similar issues arise with the ontological grouping devised by Hickey and Davis (2003) regarding technique characteristics. One possible explanation for this situation is there are a limited number of “archetypes” of which several techniques are relative variations, such as interviews: prompting (Browne and Rogich, 2001), semantic structuring (Marakas and Elam, 1998), teachback (Johnson and Johnson, 1987), closed and open (Davis, 1982), to name a few.

The development of appropriate dimensions to classify and distinguish elicitation techniques is beyond the scope of this manuscript. However, it is possible to envision some of the characteristics these dimensions should possess: some degree of independence or orthogonality, such that the addition of a dimension usefully discriminates among techniques; the possibility of judging elicitation techniques across a continuous scale anchored at extremes instead of classification via discrete categories; and finally, a mechanism making it possible to relate these dimensions to the logic of fit employed in the research model, in this case the reduction of uncertainty and resolution of equivocality. As an example of the first two issues, Tsumaki and Tamai (2005) grouped techniques along an open-closed axis (related to properties of the target space, such as stability) and a static-dynamic axis (whether techniques captured static structures or dynamic behaviors of the target domain). The authors were then able to classify seventeen techniques which differed in varying degrees across these two dimensions.

Fit and Requirements Determination Success

Whereas earlier contingency models of elicitation drew on reduction of project uncertainty as the logic for their performance effects (Davis, 1982; Naumann, et al., 1980), the iteration developed by Hickey and Davis (2004) is largely atheoretical. The main proposition of this research is systems development projects can be usefully conceptualized as situations requiring the successful processing of information to achieve their stated objectives. This statement is fully in accordance with the seminal work of Davis (1982) and Naumann, et al. (1980). However, where extant literature has focused on overall project uncertainty, this research incorporates the notion of equivocality to provide a more comprehensive understanding of the dynamics of the elicitation process. Also, departing from past research, this model distinguishes between sources of uncertainty and equivocality instead of considering only overall levels of each for the project, with the intention of providing a more specific matching of techniques to contingencies.

The application of information processing theory to information systems research is not novel (Barki, et al., 2001; Premkumar, et al., 2003), although it has not been extensively developed in the IRD literature. Although early formulations, as discussed above, employed uncertainty as the tying force behind their models, neither this concept nor equivocality, which was suggested for inclusion by Fazlollahi and Tanniru (1991), have been the subject of theorizing beyond providing a conceptual linkage between project contingencies and elicitation approaches.

The matching logic employed in any contingency model is by necessity closely tied to the conceptualization of performance or success expected from high levels of fit. The main argument of information processing theory is organizations process information in order to reduce uncertainty and resolve equivocality to levels acceptable for successful performance of the task of interest (Daft and Lengel, 1986). However, the IRD literature has not yet converged on a commonly accepted definition of success, although several and somewhat similar conceptualizations have been proposed: requirements need to be consistent, accurate, complete and agreed upon by users and developers (Naumann, et al., 1980); correct and complete (Davis, 1982); consistent, correct, and unambiguous (Yadav, 1983); stable, correct, clear, adequate, unambiguous, and usable (Wallace, et al., 2004).

Other authors, most notably Browne and Pitts (2004) have focused on analyst stopping behavior by studying the different heuristics analysts employ to reach successful conclusion of the elicitation session. To our knowledge, no such work at the level of the determination process as a whole has been conducted. Several researchers have, however, offered lists of requirements categories applicable to information systems in general, such as goals, processes, tasks, and information (Browne and Rogich, 2001); information requirements, process, behavior and problem frame understanding (Byrd, et al., 1992); or behavior, process and data (Maiden and Rugg, 1996).

Conclusion

The most important contribution of this work lies in the provision of a theoretically-grounded logic to understand why different techniques would perform better in specific project situations. A common underlying structure emerged from the synthesis of several conceptual models of the technique selection process. This research program seeks to provide organizing frameworks for each of the main components of the research framework thus developed.

In the past, authors have limited the conceptualization of these components to lists of contributing factors, but no comprehensive models to organize and understand the effects of these issues have been elaborated. The research model described in this work sets the stage for further examination of its components (e.g. contingencies, techniques, logic of fit and performance measure). Further research into the nature and impacts of the different communication obstacles is needed before they can be meaningfully incorporated into the set of project contingencies.

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Table 1. Reviewed contingency models

Model	Focus	Contingencies	Techniques	Fit Logic
Naumann et al (1980)	RV	Project size Degree of structuredness User task comprehension Developer task proficiency	Accept user statement Linear assurance process Iterative assurance process Experimental assurance process	Uncertainty level
Davis (1982)	RE	Utilizing system: Existence of a well-understood model of the system Stability of system structure Nonprogrammed versus programmed activity Stability in information use Application: High-level versus low-level application Complexity Number of users Users: Experience with utilizing system Experience with application Analysts: Experience with utilizing system Experience with application	Asking Deriving from an existing system Synthesizing from utilizing system Discovering from experimentation	Uncertainty level
Burns and Dennis (1985)	DM	Project uncertainty: Degree of structuredness User task comprehension Developer task proficiency Project complexity: Project Size Number of users Volume of new information Complexity of new information	System lifecycle Mixed methodology Prototyping	Uncertainty level Complexity level
Maiden and Rugg (1996)	RE	Purpose of requirements Internal filtering of knowledge Observable phenomena Acquisition context	Observation Interviews Protocol Analysis Card Sorting Laddering Repertory grids Brainstorming Rapid prototyping Scenario analysis RAD workshops Ethnographic methods	

Table 1. Reviewed contingency models

Model	Focus	Contingencies	Techniques	Fit Logic
Ratbe, King and Kim (2000)	DM	Project uncertainty: Level of application support Stability of user requirements Degree with which the application system is understood Degree of structure Developer's experience Top management support Project complexity: Size of the project Time constraint imposed Complexity of the application User's system experience	Systems development lifecycle Prototyping level I Prototyping level II Prototyping level III End-user development	Approaches prescribed in prior research
Hickey and Davis (2004)	RE	Inherent characteristics of the organization and project: Specific methodology to be used Level of resources or time constraints Degree of personnel turnover Characteristics of customers and users: Number of different users Diversity of needs Level of experience Willingness to work together to reach consensus Ability to articulate requirements Characteristics of the developers: Experience with the problem and solution domain Experience with software development Characteristics of analysts: Leadership skills Communication skills Analytical skills Technical knowledge Problem domain: Problem understanding Problem complexity Application domain Importance of specific non-functional requirements Existing system (manual or automated) Solution domain: Type of solution anticipated Development strategy (in-house, outsourced, COTS)	Any technique that helps elicit requirements from stakeholders	Matching: Technique characteristics Situation characteristics State of requirements

Table 1. Reviewed contingency models

Model	Focus	Contingencies	Techniques	Fit Logic
Tsumaki and Tamai (2005)	RE	<u>Application domain stability:</u> Knowledge of target domain Experience developing similar systems <u>Requirements engineers type:</u> Logical and systematic vs. intuitive and imaginative <u>Information resources:</u> Abundance of information in documents or knowledge bases Investigation of existing systems <u>User involvement:</u> Needed or just collaboration (when formal sources available) Constraint on certain techniques (e.g. brainstorming) <u>Non-functional requirements</u>	Domain decomposition Goal-oriented approaches Scenario-based approaches Brainstorming	Elicitation operation types (static vs. dynamic) Target object types (closed vs. open)

RV = Selection of a requirements validation technique
RE = Selection of a requirements elicitation technique
DM = Selection of a development methodology

Table 2. Grouping of task-related contingencies

Task Dimension	Factors	Sources
Task analyzability	Degree of structuredness	Degree of structuredness (Naumann, et al., 1980), stability of system structure (Davis, 1982), programmed vs. nonprogrammed activity (Davis, 1982), degree of structuredness (Burns and Dennis, 1985), degree of structure (Ratbe, et al., 2000).
	Application level	High-level vs. low-level application (Davis, 1982), application domain (Hickey and Davis, 2004), level of application support (Ratbe, et al., 2000).
	Complexity	Complexity (Davis, 1982), complexity of new information (Burns and Dennis, 1985), complexity of the application (Ratbe, et al., 2000), problem complexity (Hickey and Davis, 2004).
Task variety	Project size	Project size (Naumann, et al., 1980), number of users (Davis, 1982), project size and number of users (Burns and Dennis, 1985), size of the project (Ratbe, et al., 2000), number of different users (Hickey and Davis, 2004).
	Application level	High-level vs. low-level application (Davis, 1982), application domain (Hickey and Davis, 2004), level of application support (Ratbe, et al., 2000).
	Complexity	Complexity (Davis, 1982), complexity of new information (Burns and Dennis, 1985), complexity of the application (Ratbe, et al., 2000), problem complexity (Hickey and Davis, 2004).
	Volume of information	Volume and complexity of new information (Burns and Dennis, 1985).
Task-possessed information	Comprehension / understanding	User task comprehension (Naumann, et al., 1980), existence of a well-understood model of the system (Davis, 1982), user task comprehension (Burns and Dennis, 1985), degree with which the application system is understood (Ratbe, et al., 2000), problem understanding (Hickey and Davis, 2004), knowledge of target domain (Tsumaki and Tamai, 2005).
	Experience	Experience with utilizing system and application (Davis, 1982), developer experience and user system experience (Ratbe, et al., 2000), level of experience, experience with the problem and solution domain (Hickey and Davis, 2004), experience developing similar systems (Tsumaki and Tamai, 2005).
	Other sources of information	Observable phenomena (Maiden and Rugg, 1996), existing system (Hickey and Davis, 2004), abundance of information and investigation of existing systems (Tsumaki and Tamai, 2005).