An Integrated Human Information Behavior Research Framework for Information Studies

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Human information behavior is emerging as an important component of information studies. As in many emerging research areas, one challenge is to identify important facets of human information behavior and understand how different methods can be best used to research these facets. This paper presents the framework of an approach to designing and synthesizing research studies in human information behavior. The framework emerges from previous research in human information behavior and incorporates Ranganathan's framework for knowledge organization. It proposes that research studies that investigate human information behavior should consider the following facets: personality, matter, energy, space, and time. Personality refers to actors, and in this framework includes participants and their social networks. Matter refers to the target of the action. It includes information and information resources, including services and technology that may provide access to information. Energy is the action itself, including the participants' tasks, processes, and goals. Space is the environment of the action, and includes physical space as well as organizational and sociopolitical contexts. Time is the nonspatial continuum in which actions and events occur; in the framework, time is considered an episode, interval, or eon. Facets that should be investigated and taken into account in a study help guide the selection of the research methods for the study. Furthermore, research results from multiple studies can be synthesized by understanding the relationships among the facets investigated in the different studies.

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Information studies, an interdisciplinary field involving both scientific research and professional practice, has its origins in the scientific and technical advances following World War II (Saracevic, 1992). It has strong ties to library science, computer science, and cognitive psychology, as well as to communication and other behavioral and social sciences. Its goal is to add understanding and solve problems through the discovery and implementation of models and theories focusing on human information behavior in the context of social, institutional, or individual needs, or a combination thereof and uses of information and the communication of knowledge. In recent years, there has been some discussion about which research methods are most appropriate for achieving these goals (e.g., Fidel, 1993; Hernon & Schwartz, 1994; Kuhlthau, 1993; Liebscher, 1998; Wildemuth, 1993). Traditionally, quantitative methods, such as experiments, bibliometrics, and surveys, were predominantly used in information studies research. In recent years, there has been increased discussion and use of qualitative methods, such as participant observation and unstructured interviews. However, because qualitative research investigates a single setting or situation, it has been criticized for its apparent dependency on a particular person or group of individuals, place, and time, and apparent lack of validity, including reproducibility.

A challenge is to understand how research methods can be best used in information studies research. To address this challenge, this article proposes an integrated research framework that provides an approach to combining multiple methods in a consistent manner. The approach is evolutionary rather than revolutionary. It emerges from previous research in information studies, incorporates Ranganathan's framework for knowledge organization, and combines methods that originated in a variety of fields including communication, sociology, and psychology. It is based on the assumption that human information behavior, including the seeking and communication of knowledge, is multifaceted. In various processes and situations these multiple facets, or factors, occur together and affect each other. In the proposed framework, various research methods are integrated or combined to give insights from different points of view and, perhaps, serendipitous results not otherwise possible. The framework has emerged over several years through designing and conducting studies that explored human information behavior in a variety of situations (e.g., Iivonen, 1995a, 1995b, 1995c, 1995d, 1996; Iivonen & Sonnenwald, 1998; Sonnenwald 1992, 1993, 1996; Sonnenwald & Lievrouw, 1997). It can be useful as a tool in designing research, comparing research results, and teaching research methods, and regarding human information behavior in general.

RELATED APPROACHES

Use of Multiple Methods

Increasingly, research in information studies combines multiple methods to research human information behavior because doing so can provide a more holis-

tic and comprehensive view of information behavior, increase the validity of research results through data and methodologic triangulation, or both. The following examples illustrate this point. Kuhlthau (1993) conducted a series of five studies to develop a model of the information search process. In the first study she primarily used qualitative methods. She collected multiple types of qualitative data including journal, search logs, short written statements, interviews, conceptual maps, and teachers' assessments. Her analysis of these data lead to a model of the user's experience in the process of seeking information. The subsequent four studies verified and refined the model. Two studies focused on large-scale verification of the model. Quantitative methods, including a process survey and flowcharts of the information search process, were used to collect data about the experience of the information search process by approximately 400 academic, public, and school library users. The final two studies focused on longitudinal verification of the model. Kuhlthau used both quantitative (a perception survey) and qualitative (interviews) data to determine if students' perceptions of the information search process changed over time. By conducting an integrated series of studies that used multiple data collection techniques, Kuhlthau developed and verified a general model of the information search process.

Similarly, Wildemuth (1993) conducted a series of three studies using different methods in each study to investigate end-user adoption and use of information technology. She first used interviews in an exploratory manner to develop a preliminary understanding of end-users' behaviors. Then building on this understanding, she conducted experiments that investigated end-users' search behaviors.

Kuhlthau, Wildemuth, and others developed their individual approaches to research in human information behavior using multiple methods. A general framework to guide the selection and application of multiple methods may further facilitate research design and advancement in library and information studies.

Research Frameworks

Several frameworks to guide research, and subsequently the selection of research methods, in information studies have recently emerged. One such framework, proposed by Rasmussen, Pejtersen, and Goodstein (1994), is called Models of Human Activities in Work Context (MOHAWC) and suggests several dimensions of cognitive work that should be analyzed. These dimensions include:

- *Work domain problem space*, which is a description of the goals, task functions, and available tools in each domain that need to be considered as possible information sources.

- *Tasks*, that is, a representation of tasks in the work situation. This dimension delimits the information needed to be considered during analysis. It includes a representation of the possible states of knowledge and corresponding information that a person may run through when solving problems or processing information in a given task situation.
- *Mental strategies, heuristics, and tactics*, or ways of thinking that can be applied during cognitive tasks. This is a representation of the participants' mental models of the work domain and task situation.
- *Role allocation*, or assignment of roles to individual participants performing tasks. This is a representation of the way participants informally organize and share their work, including their cooperative work patterns and how they may interact during those activities.
- *Management style and culture*, that is, managerial or formal organizational norms, and assignment of work tasks and job responsibilities, including decision making.

The framework further suggests that each dimension can be fully described using a means-end representation. The means-end representation is structured in five levels of abstractions. The highest level of abstraction describes the goals and constraints in a domain that control a task, cognitive activity, or mental strategy, and so forth. The next level of abstraction specifies the priorities and measures used to determine the importance and criteria for achieving the various goals and constraints. The third abstraction level describes the general activities and functions that can be used to achieve the goals and satisfy constraints measured by the priority measures. The next level describes actual physical activities and processes, or routines, that are used in the general functions. The lowest level of abstraction represents the physical anatomy of a system or physical objects that are used in the physical activities. The purpose of these abstraction levels is to identify concepts and the relationships among them to characterize or represent an entity.

Data collection techniques used in the MOHAWC framework include structured interviews, verbal task recordings, and surveys in which data concerning prototypical tasks, decision-making processes, and work organization are collected. A limitation of the framework is its primary focus on cognitive and task aspects of information behavior; it does not explicitly incorporate or support the discovery of social aspects of information behavior or information processes.

A general theoretical model of information behavior is presented by Wilson (1981, 1997). In the first stage (Wilson, 1981), the model was presented as a model of information-seeking behavior. At that time it included:

- An information need that was defined as a subjective experience that occurred in the mind of a person in need. Information need was connected to the physiologic, affective, and cognitive states of a person.

- The social role, which affects information need and information-seeking context.
- The environment, which also affects information need and information-seeking context.
- Personal, role-related, and environmental barriers of information-seeking behavior.
- The information-seeking process.

Later, Wilson (1997) expanded the information-seeking behavior model, extending its focus to information behavior in general. The new model included:

- Context of information need;
- Activating mechanism, both stress and coping factors; risk and reward methods as well as learning and self-efficacy were added to the model;
- Intervening variables, which included psychologic, demographic, role-related, and interpersonal factors as well as environments and information source characteristics;
- Information-seeking behavior, which was specified to be passive attention, passive search, active search, or ongoing search; and
- Information processing and use.

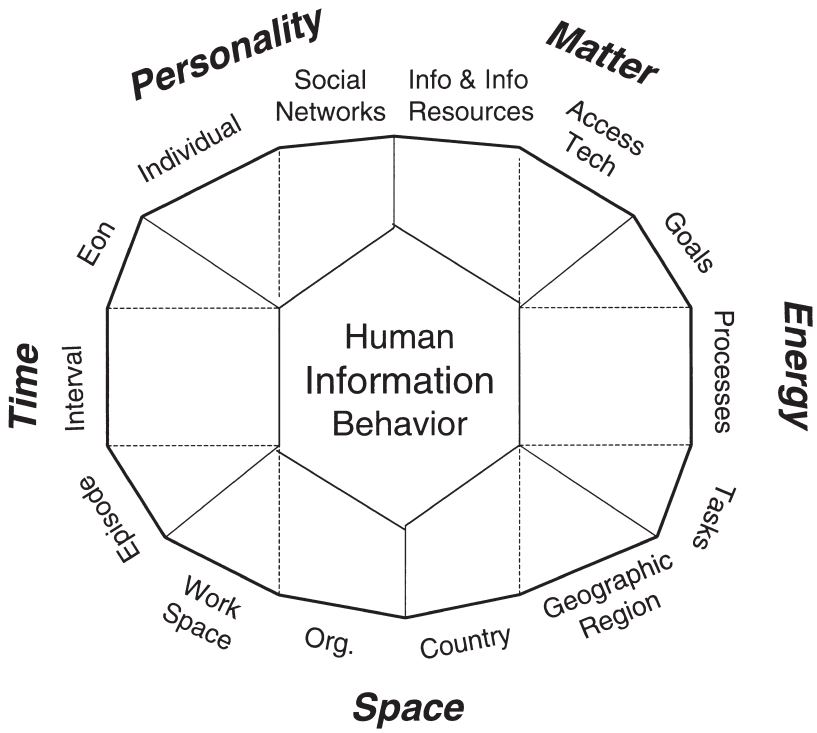
Wilson presented his model as a theoretical one and did not discuss how to obtain or collect data to manifest the model, making the model visible. He suggested that the model could be used to analyze the existing information science literature and identify new research interests and questions. There is also a need to discuss which kind of methods could be used in this future research and to build on these approaches to suggest an integrated framework to guide research design.

AN INTEGRATED HUMAN INFORMATION BEHAVIOR APPROACH FOR INFORMATION STUDIES

Conceptual Framework

The human information behavior approach for information studies proposed here is a conceptual framework for designing research studies that explore such behavior in the context of social, institutional, individual needs, or a combination thereof, and uses of information. It is based on the premise that human information behavior does not occur in isolation; it is shaped by multiple facets, or factors (Sonnenwald, 1999). Because of the multiplicity of facets and complexity of each facet, an integrated series of studies using multiple research techniques may be required to explore and understand more fully human information behavior.

FIGURE 1
The Conceptual Framework



The facets, illustrated in Figure 1, emerged from a metananalysis of previous studies of human information behavior in search processes and design and engineering situations conducted by the authors. That is, in the tradition proposed by Schön (1983), the authors, as research practitioners, reflected on their experiences in human information behavior studies to develop an epistemologic model of research practice. When reflecting on the type of information and data found to be important during the research process, facets or categories of information emerged. The facets are analogous to the basic categories of knowledge organization presented by Ranganathan (1957). Ranganathan proposed that knowledge can be organized into facets of personality, matter, energy, space, and time, known as the PMEST system. Facets can be understood as a manifestation of categories, that is, as groups of concepts that are related to the topic of a facet. For example, each concept in the personality category represents or describes actors. The purpose of the personality facet is to explain who is acting. Similarly, all concepts in the time facet explain or elaborate the concept of time, in one form or another (Ranganathan, 1963). The same categories mentioned by Ranganathan emerged in the authors' analysis of research studies. The categories appear to provide a framework for designing research studies that investigate human information behavior.

The first facet in Ranaganathan's system is *personality.* In his system, personality is related to the context and explains or describes actors, or subjects of action, in a context. In the framework presented in this paper, personality consists of participants and their social network(s). It is well documented that individual preferences, abilities, and affects influence information behavior, such as information resource selection and searching strategy (e.g., Borgman, 1989; Kuhlthau, 1993). People do not, however, act only as individuals but also as members of various groups. Social networks may influence information behavior by providing access to information and knowledge resources and expectations or norms with respect to information behavior. For example, an individual's professional social network may provide opportunities, such as conferences, journals, newsletters, and listservs, for members to discuss and exchange information. A professional social network may also determine which information resources are appropriate for given situations. For instance, reviewers of a conference or journal paper help determine the references that should be used in the paper. Thus individuals' preferences and social networks may influence human information behavior and merit research.

Ranganathan's second facet is *matter*, which is the target of action. In the framework, matter includes information and information resources, as well as information and communications technology that may provide access to information. It can be important to identify the information and information resources and tools used and, perhaps, ignored by participants to understand more fully human information behavior. At issue is whether to conceptualize individuals, such as reference librarians and professional searchers, as "matter" when they provide information. They are included in the personality facet because they have individual preferences, abilities, and affects that influence how they provide information and search for information (e.g., see Wu, 1993; Iivonen & Sonnenwald, 1998). However, the information they provide is considered matter. Although information systems, controlled vocabularies, and other information resources are created by individuals and inherently include those individuals' preferences, they do not fully embody the abilities and affects of the individuals who created them and thus are considered matter, not personalities.

The third facet is *energy*, which, in Ranganathan's perspective, includes problems, processes and activities. In other words, energy refers to the action and the factors that cause the action. Thus in this approach, energy includes the participants' problems or goals that motivate or give rise to human information behavior, the processes participants use, and the tasks (including subtasks or activities) that comprise those processes. Each process contains tasks, and these tasks may require or produce (or both) specialized information as well as coordination and collaboration among participants. Thus tasks, processes, and goals can motivate and influence human information behavior.

The fourth facet is *space.* The term *space* is used in this approach to include not only the work, or task, space but also the organizational and the larger sociopolitical and socioeconomic context. An organization often sets norms and cultural expectations with respect to information behavior; for instance, in one

project studied, team members reported that they could only discuss their work with the people their manager told them they could discuss it. In their organization, communication was equated with control; people interacted and shared information with others to control them. However, this norm did not hold for other organizations studied. Different rules, or norms, for information behavior may originate at national levels. In the United States, for example, norms dictate that a variety of topics including politics and religion should not generally be discussed among coworkers. In countries such as Denmark, politics and religion are viable discussion topics. Norms such as these may influence interpersonal communication strategies that are part of larger information behavior strategies. As teams and organizations increasingly create multiorganizational and international projects, participants may have a variety of norms and expectations, all of which contribute to the complexity of interaction among participants and their human information behavior.

The fifth facet is *time*, the nonspatial continuum in which actions and events occur. Time is an important unit of analysis; what is observed, or considered important, is often delimited by time. In the human information behavior studies analyzed, three temporal aspects were differentiated: an episode (short period of time), an interval (longer period of time with a distinct starting and ending), and eon (a long, continuous period of time). The time frame to be investigated influences the type of data collected and also the type of research results possible.

Of course, each of these facets may be subdivided into smaller facets. For example, consider the personality facet. Individual characteristics, such as general cognitive ability, spatial reasoning ability, and work history or job performance, may or may not influence information behavior. Some of these characteristics are extremely important in other fields, for instance, cognitive and perception abilities are important in psychology and cognitive psychology. A challenge in information studies is to understand in what way these characteristics are important in information situations.

This may be further complicated because instances of facets may be hard to differentiate. The framework proposed here can be compared with gemstones, for which it is not always easy to differentiate facets when light is being refracted from one facet to another, and the same may be true in information situations. It may be difficult to differentiate facets because data can be elusive, difficult to obtain or observe directly, and ambiguous in their significance.

We do not propose that the facets and facet categories illustrated in Figure 1 are necessary and sufficient to research all instances of human information behavior. In some sense, each type of information need and use situation or research question concerning information behavior may be considered an uncut gemstone. The process of studying the situation or exploring a research question may be similar to studying or building an understanding of how to cut a gemstone. It is a process of understanding which facets are most important to the research questions or goals. The same stone can be cut differently yet with equally brilliant results, depending on your goals.

A variety of methods may be used both in collecting and analyzing data concerning the facets of human information behavior.[1] Data collection methods include:

- *Surveys* using structured interviews or questionnaires, increasingly in an online format (e.g., Bailey, 1994; Tillotson, Cherry, & Clinton, 1995);
- *Theme, or in-depth, interviews*, including semi- and unstructured interviews, sense-making interviews, and critical incident interviews (e.g., Chatman, 1992; Dervin, 1992; Flanagan, 1954; Kuhlthau, 1993; McCracken, 1988);
- *Naturalistic or participant observation* (e.g., Adler & Adler 1987; Fidel, 1991a, 1991b, 1991c; Solomon, 1997);
- *Experiments or quasiexperiments* including think-aloud experiments (e.g., Ericsson & Simon, 1992; Fidel 1991a, 1991b, 1991c; Ingwersen, 1984; Saracevic, Kantor, Chamis, & Trivison, 1988);
- *Psychological testing* including the testing of cognitive and learning styles (e.g., Bellardo, 1984; Logan, 1990; Saracevic & Kantor, 1988);
- *Document collection*, that is, the use of historical or other documentation such as books, reports, and memos (e.g., Genz, 1993);
- *Diaries* and *logs* (e.g., Borgman, Hirsch, & Hiller, 1996; Fabritius, 1998); and
- *Collection of bibliographic data* (e.g., Campanario, 1996; Kajberg, 1996; Rousseau & van Hooydone, 1996).

Data analysis methods can include:

- *Statistical description and testing* (e.g., Bellardo, 1984; Saracevic et al., 1988);
- *Explanation and model building* (e.g., Dervin, 1992; Fidel 1991a, 1991b, 1991c; Kuhlthau 1993);
- *Discourse analysis*, including conversational analysis (e.g., Frohmann, 1994; Solomon, 1997; Wu, 1992);
- *Content analysis* (e.g., Chang, 1995; Krippendorf, 1980; Strauss & Corbin, 1990);
- *Social network analysis* (e.g., Haythornwaite, 1996; Sonnenwald & Lievrouw, 1997; Wellman & Berkowitz, 1998);
- *Historical or time-series analysis* (e.g., Makinen, 1997; Richards, 1996); and
- *Bibliometric analysis* including citation analysis (e.g., Campanario, 1996, Kajberg, 1996; Rousseau & van Hooydone, 1996).

To help disambiguate the facets and their role in human information behavior, multiple studies, multiple methods, or both can be used. For example, to in-

1 Several different typologies of data collection and data analysis methods exist, and often the boundaries between data collection and data analysis methods are not clear or even evident (e.g., see Busha & Harter, 1980; Järvelin & Vakkari, 1992).

crease the generality and validity of results, multiple studies investigating information behavior in similar settings can be conducted. Of course, personalities, matter, energy, space, and time are never identically replicated, but fundamental findings may be enhanced and replicated in subsequent studies, increasing the generality and validity of research results. In addition, a triangulation approach (Denzin, 1989) using multiple methods can be used to extend and validate results further. For example, quantitative methods, such as sociometric surveys, can help focus or confirm (or both) phenomena and relationships originally detected through qualitative methods. Quantitative methods have an additional advantage in that they can more easily include a large number of study participants than qualitative methods, although they typically only do so in any given study for a limited number of facets. There is much more that may be said concerning the interaction between quantitative and qualitative methods. The research examples that follow illustrate some of these interactions.

Limitations

This framework suffers from several limitations. It is perhaps more human resource- and time-intensive than other types of research, such as research in information retrieval algorithms. Research involving personality, matter, energy, space, and time facets often requires a large amount of human resources and time. For example, conducting research that investigated personality, matter, energy, and time facets of human information behavior in design required 2 years of full-time effort to develop an exploratory model (Sonnenwald, 1993). Other multimethod approaches may also suffer from these limitations. Research always needs particular resources; either time, money, human capacity and input, or physical equipment. There are, however, great benefits from multimethod, multistudy research programs in terms of the multifaceted views of information behavior they provide. Ideally, funding agencies and organizations recognize and appreciate differences in research processes and research results.

A second limitation is that it cannot demonstrate that the framework is complete. This is a general limitation of frameworks and models. It is often only through use of and reflection on the framework that researchers and practitioners can come to understand its strengths and weaknesses better.

USING THE FRAMEWORK IN INFORMATION STUDIES: TWO EXAMPLES

The following examples illustrate the use of the framework in information studies. The examples demonstrate how the framework can facilitate research design and the synthesis of research results in a consistent manner.

Human Information Behavior in Multidisciplinary, Multiorganizational Teams

Increasingly, multidisciplinary and multiorganizational teams are required to solve complex problems, design products, and deliver services. In these situations, the personality facet plays an important role. Individuals often bring unique knowledge, skills, work practices, and expectations that they must explore and integrate to be successful. Professional social networks often legitimatize certain information resources and types of information and discourage the use of others. When team members come from different disciplines, their evaluation of information and information resources (matter) provided by other team members may or may not conform to the expectations found in their own discipline. Furthermore, access to information (the matter facet) influences team members' information behavior, for instance, information about cutting-edge technology may be required to produce innovative components of products (e.g., see Sonnenwald, 1996). The problems, goals, formal and informal work processes, and tasks (the energy facet) can influence what information team members need and how they may need to share that information. The team may be one work unit, but it will have connections and responsibilities to multiple organizations, for instance, each organization from which a team member comes, that funds the team (the space facet), or both. Thus information flow to and from multiple organizations can be an important component of team performance. In addition, information behavior may change over time as the goals and tasks of the team change (the time facet). Thus personality, matter, energy, space, and time play integral roles in human information behavior in multidisciplinary, multiorganizational teams. Understanding human information behavior in these complex situations may yield better work and organizational practices, and information services and tools that effectively support collaboration in multidisciplinary and multiorganizational teams.

Table 1 illustrates the sequence of data collection methods that were used over a period of 5 years to investigate human information behavior in multidisciplinary design teams. Document collection methods were used to start the architecture and expert system case studies, the first two studies. These studies provided the opportunity to investigate multiple facets, including personality (individuals and social networks), matter (information and information resources), energy (problems, goals and processes), space (the organizational unit), and time (during intervals in the design process and throughout the entire design process). The primary analysis approaches used in these studies were content analysis, event-sequence analysis, and social network analysis. The third study focused on the additional subfacets of access systems and technology, tasks, organizations, and episodes. This was achieved through a longitudinal study of a telecommunications design team using interviews, participant observation, document collection, and critical incident interviews over a 14-month period (Sonnenwald, 1993). This study provided additional data on subfacets covered in the first two studies to increase the reliability of the results. Content

TABLE 1
Facets Investigated in Studies of Multidisciplinary Teams

Facets	*Architecture Study*	*Expert System Study*	*Telecommunications Study*	*Engineering Study*	*Telecommunications Study*
Personality					
Individual	Documents	Documents, Interview	Interviews, Participant observation, Critical incident interviews	Interviews	Interviews
Social Networks	Documents	Documents, Interview	Interviews, Participant observation, Critical incident interviews, Documents	Interviews	Surveys
Matter					
Information and Information Resources	Documents	Documents, Interview	Interviews, Participant observation, Documents	Interviews	Surveys
Access Systems and Technology			Interviews	Interviews	
Energy					
Problems/Goals	Documents	Documents, Interview	Interviews, Participant observation, Critical incident interviews, Documents	Interviews	Surveys, Interviews
Processes	Documents	Documents, Interview	Interviews, Participant observation, Critical incident interviews	Interviews	Interviews
Tasks			Interviews, Participant observation, Documents	Interviews, Documents	Surveys

(*Continued*)

TABLE 1
Continued

Facets	*Architecture Study*	*Expert System Study*	*Telecommunications Study*	*Engineering Study*	*Telecommunications Study*
Space					
Work Space			Interviews, Participant observation		
Organization			Interviews, Participant observation, Critical incident interviews	Interviews	Surveys
Country/ Geographic Unit				Interviews	
Time					
Episode			Interviews, Participant observation, Critical incident interviews, Documents		
Interval	Documents	Documents	Interviews	Interviews	Surveys
Eon	Documents	Documents, Interview			

analysis and social network analysis were used to analyze these data. To tie the facets together and include the additional facet of country or geographic unit, an engineering study was conducted in Europe. The result was a proposed taxonomy of roles that facilitate collaboration in multidisciplinary teams (Sonnenwald, 1995). To investigate the validity of the taxonomy specifically, surveys were conducted in the fifth study, a study of a telecommunications design team (Sonnenwald & Lievrouw, 1997). This diversity of methods across the various studies may extend, perhaps, the descriptive adequacy of the results and lead to the discovery of general patterns that may be evident over a variety of design situations.

Architecture Case Study. The first case study primarily focused on personality, matter, energy, and time facets. Participants (personality facet) in the case study included the new house owners and their family, a construction firm with four owner-employers, and an architect and his assistant. Communication and information behavior among these participants (matter facet) throughout the design process were studied. The design goal (energy facet) was the construction of a single-family house over a 10-month period. Throughout the design project, a fast-track, "design-as-you-go" process was used. In the fast-track process, the architect created plans for artifact components as construction tasks proceeded. The entire design process lasted ten months (time facet), and data from the entire ten months, or duration of the project, were analyzed.

Data for the case history came from the 300-page book, *House* (Kidder, 1985). To analyze the data, an event sequence analysis (time facet), concept or thematic analysis (matter facet), and sociometric data analysis (personality facet) were carried out to discover who interacted with whom, the content of the interaction, and the meaning participants gave to the interaction. This reconstruction was imperative to understand each design process because participants and observers reported overlapping subsets of events, not necessarily in chronological order. The concept analysis was imperative to discovering underlying concepts or themes, including the meaning participants appeared to ascribe to interactions and events. Each concept derived from this iterative process was summarized in the form of a concept diagram and topic memo that cited data examples as evidence for the concept. Results from this initial study included a preliminary conceptualization of recursive phases of the design process (energy facet), and networks (personality facet) that emerged during the phases to disseminate, integrate, and create information (matter and time facets). For example, the design process was conceptualized as five overlapping and dynamic phases: history, planning, framing, finishing, and conclusion. During the planning phase, intergroup stars emerged who planned and coordinated activities across groups within the project and represented their own group in planning discussions. All intergroup stars shared information about money and time. However, the designer intergroup star focused on aesthetics, whereas the user intergroup start focused on functionality. Similarly, when the designer intergroup star fo-

cused on design details, the developer intergroup star focused on construction theory and practices, and when the user intergroup star focused on constraints, the developer intergroup star focused on construction methods and practices.

Expert Systems Case Study. The second case study extended the research by investigating different examples of the personality and energy facets in design. The study participants included end-users who were sales people, their managers, and office staff at Digital Equipment Corporation (DEC) offices throughout the United States; software designers and software engineers were employees at DEC and Carnegie Mellon University. New team members joined each group during the design process, which occurred over a 5-year period. The team's goal was the development of an expert system, called XSEL (the eXpert SELling assistant), that was intended to assist sales staff in configuring computer systems that satisfy customer needs. The design process used to create the expert system included the ETHICS (Effective Technical and Human Implementation of Computer-based Systems) participatory design method (Mumford & MacDonald, 1989), which prescribes activities that facilitate user involvement in the design process and an iterative/prototype design approach that prescribes a succession of development and evaluation tasks until a system contains enough features to be labeled "completed." Thus the case study provided an example of a different work situation involving individuals with different professional and group affiliations in a corporate environment.

Data for this case study came from *XSEL's progress: The continuing journey of an expert system* (Mumford & MacDonald, 1989), which provides a history of the design situation from the perspective of a group manager, a business case study of the design situation (Leonard-Barton, 1987), published and unpublished papers by designers and developers (e.g., McDermott, 1982), an article on the culture of the corporation during that period (Rifkin, 1986), and an interview with a project team member. This variety of data sources provided information about technical and organizational tasks as well as interaction among participants and participants' perspectives and interpretations of interactions, tasks, and organizational culture.

The data were analyzed using the event sequence analysis, concept analysis, and sociometric data analysis methods described earlier. The result of the analysis included an expanded and more general model of information behavior and communication during the design process (Sonnenwald, 1992). For example, additional roles were discovered; more general network patterns emerged; and the earlier conceptualization of design phases was validated.

Telecommunications Field Study. The third study investigated new aspects of the time facet and different examples of the personality, energy, matter, and space facets. With respect to the time facet, this study investigated a design project as it evolved over 14 months. Thus data was collected as events

occurred. The participants (personality facet) included approximately 14 individuals from a variety of ethnic and national origins. They were predominately male and held bachelor's, master's, and doctorate degrees in disciplines such as electrical engineering, operations research, computer science, telecommunications, and business administration, and their on-the-job experience ranged from 3 to 37 years. Although most participants did not work full time on the project, some worked full time for intermittent time spans. The participants' primary project goal (energy facet) was to create a telecommunications network architecture and management system that would support data, voice, and video communications. Tasks included determining customer requirements, developing business plans, conducting technical analysis of telecommunications network components, and synthesizing new technologies into a potentially viable product. The team exchanged information during formal and informal face-to-face meetings, memos, and technical papers (matter facet). The project had begun before data collection began, and the project continued for a short interval after data collection ended. Thus the time facet for this study is classified as episode and interval.

Team members worked in various engineering units of a research and development corporation that employs several thousand technical employees in the United States (space facet). In addition, most participants were physically located in different office buildings up to 50 miles apart. This study provided an example of another type of multidisciplinary team situation in a large, structured corporate environment and provided the opportunity to collect data about the design process as it evolved.

Multiple, coordinated research methods, including unstructured interviews, participant observation, critical incident interviews, and document collection, were used to gather data on facets of communication and information behavior. Using multiple methods provided flexibility for gathering data from a range of data sources, including participants, colleagues performing related tasks in the corporation, technical papers, meeting minutes, viewgraphs, and memoranda. Data from 41 unstructured interviews, 19 participant observation periods, 14 critical incident interviews, and 125 documents were collected over a 14-month period. This approach provided a wealth of information about the experiences and perceptions of participants and changes over time, expressed and explained by their own language and action.

In this study, analysis began with two steps (Lofland & Lofland, 1995): physical data organization and logical data organization. Physical data organization was carried out continually throughout the study. Statistics about observations, interviews, collected documents, and surveys were logged as they occurred. Field notes, documents, and survey data were organized in chronological order with cross references as appropriate.

Logical data organization included a semantic concept analysis and empirical coding. The goal of the semantic concept analysis was to discover who interacted with whom, the content of the interaction, and the meaning that partici-

pants gave to the interaction. All field notes and documents were analyzed to discover underlying concepts, or patterns, in the answers to these questions. The results were summarized in topic memos that included descriptions and evidence of concepts discovered in the analysis. Empirical codes, or indicators, that were identified during model development were used as a basis for categorizing field notes and documents and discovering additional patterns in the data. For example, a list of themes discovered during model development was augmented by additional themes discovered in the semantic concept analysis. The combined list was used to classify themes in each document, and the results were used to develop further insights about intragroup and intergroup information dissemination. In addition, coding helped identify the frequency and direction of information dissemination via documents among groups. For example, a theme discovered during model development and augmented during the semantic concept analysis was the theme of communication being equated with control. Communication was seen as an instrument to persuade others; it was not seen as a way to share perspectives or create new knowledge. Participants reported the purpose of their interaction as to "educate the user," "tell [others] the truth," "enlighten," and "to simulate [others] in the direction I want to move them." During document analysis, document text was analyzed to determine if this theme also emerged in their written language. Only one document of 125 was found to use language that suggested communication could be used to create knowledge. In this document, sent by users to designers and developers, the users wrote that they "would welcome the opportunity to work with individual(s) . . . to define and understand [their] requirements" (Sonnenwald, 1993).

Results from the semantic concept analysis and coding were combined in a triangulated strategy to explore information behavior from multiple vantage points. For example, one explanation for the relatively low activity in the developer intragroup document network that was discovered in the process of coding documents could simply be that developers preferred other ways to share information, for instance, through face-to-face communication. However, data from participant observation and interviews revealed relatively low interaction of all types among developers. When viewed collectively, the data suggested that a weak intragroup network existed among developers.

These results were synthesized with results from the earlier studies, and a theory of "contested collaboration" emerged (Sonnenwald, 1993, 1995). Contested collaboration posits that design participants enter the project with preexisting individual and group patterns of work activities, social organizing, and personal beliefs. That is, they have unique life-worlds[2] or domains and perspectives. Participants must mutually explore each other's life-worlds and at the

2 The concept of life-world, introduced by Schutz and Luckman (1973), refers to "the quintessence of a reality that is lived, experienced, endured . . . a reality that is mastered by action and the reality in which—and on which—our action fails" (Schutz & Luckman, 1973, p. 1).

same time bring their own life-world knowledge to bear in the process of design. However, this collaboration and information sharing is often difficult because of the very uniqueness of each member's life-world, which is expressed through differences in language, expectations, motivation, and sense of quality or success. In addition, participants often need to explore their own specialized knowledge more deeply to develop creative solutions to design problems. This may further increase differences among participants. As a result of these differences, participants may contest, or challenge, each other's contributions, either overtly or covertly. They may try to use various types of communication and information strategies to help resolve their conflict; however, organizational and cultural norms may keep such strategies from emerging.

Engineering Design Field Study. The purpose of the fourth study was to evaluate and expand the models and theory that emerged from the preceding studies. To achieve this, various facets investigated in the fourth study were dissimilar to those in the previous studies. The design team included 27 participants with on-the-job expertise and technical degrees in mechanical engineering, chemical engineering, material science, electrical engineering, software engineering, production, environmental engineering and applications, and marketing (personality facet). The project goal was to create a new sensor to be used for environmental purposes; tasks included designing mechanical and electromechanical components, developing a material collection and analysis strategy, and developing software to collect and synthesize measurements collected by the sensor (energy facet).

The project took place in northern Europe (space facet). Most participants worked for a leading international producer of precision mechanical and electronic components. Several participants worked in different divisions within this company and were located in different parts of a large office and manufacturing complex. Other participants worked for consulting firms located in two different cities, approximately a 1-hour flight apart. Still, other participants worked in another country for different organizations. The information behavior was studied over a 3-month interval (time facet) to investigate a particular 'slice of time' of a design situation. Because the participants came from different disciplines, companies, and countries, faced a different type of design goal, and were studied during the middle of the design process (personality, space, energy, and time facets), this study extended the previous research.

Over a 3-month period, semistructured interviews were conducted with 24 participants. The average length of the interviews was 2 hours (their length ranged from 1 to 8 hours), and interviews were conducted with approximately 89% of the participants in the design project (i.e., 24 of 27 participants.) The purpose of these interviews was to learn about participants' past design experience, their current design tasks, and the nature, content, and their perspective of project-related information needs, use, and dissemination behavior. Notes were taken during each interview and augmented after each interview by draw-

ing the interview setting, expanding on topics discussed by the interviewee, and writing immediate impressions about the interview. Additional data came from documents such as organization charts, documentation on formal design methods used by participants, and samples of their drawings and reports that were provided during the interviews. A total of 154 work-related interactions or communication–information links were described during the interviews, 134 of which were reciprocally mentioned (i.e., participant A described interacting with participant B and participant B described interacting with participant A). This is a very high percentage of concurrence among the study participants and validates the accuracy of the research approach.

An expanded model of roles emerged from the analysis. These roles are an important aspect to information behavior in the design process as predicted by the concept of contested collaboration. Thirteen roles were identified. These roles span organizational, task, discipline, and personal boundaries, and several roles span multiple boundaries (see Sonnenwald, 1995). Examples of roles include the interdisciplinary star who integrates knowledge from different disciplines to create solutions to design problems, and the agent who facilitates interaction and arbitrates conflict among all design team participants. Previous research (e.g., Allen, Lee, & Tushman, 1980; Tushman, 1979; Tushman & Katz, 1980) limit their perspective on boundary spanning to formal project, department (or laboratory), and company (or corporate) boundaries. These results illustrate how information behavior must span a variety of boundaries in multidisciplinary team situations.

Telecommunications Study. The purpose of the fifth study was to begin to evolve the descriptive model into a prescriptive model. Models of the design process have traditionally focused on design tasks and task management (e.g., Hubka 1989; Yourdan 1989), and information behavior among design participants has not been explicitly discussed in these methodologies. However, studies (e.g., Curtis, Krasner & Iscoe, 1988; Kraut & Streeter, 1995; Sonnenwald, 1993) indicate that communication and information behavior is often difficult for design participants and affects project outcomes. Furthermore, previous studies of information behavior among multidisciplinary teams have focused primarily on information resources used by teams, including reference manual, journals, and trade magazines.

Based on the results of the previous studies and understanding of the type of data from which these results emerged, relationships among personality, matter, and energy facets were explored. In particular, relationships among communication roles, social networks, design tasks, and individual and project team performance.

Data were collected from an ongoing design project in a multidisciplinary telecommunications design team in California. An initial set of interviews were conducted with the project team leader to learn about the individual team members and the project goals. Surveys, including sociometric surveys and a

performance perception survey, were used to collect data about participants, team and team members' project goals and tasks, information and communication patterns, and individual and team performance over a 2-month period.

Analysis methods included social network analysis and multivariate analysis to identify patterns of information behavior and their relationships to project performance. Contacts and links among team members were calculated, and descriptive statistics for the whole network (density, connectivity) and for individual members (centrality) were calculated. Means and standard deviations were calculated for each item in the performance perception survey. Correlations among the individual interaction ratings (how team members rated their interaction with one another), effectiveness ratings (how team members rated the effectiveness of other team members), and the number of contacts and links (centrality) reported for each team member were also calculated. Gower's canonical analysis of asymmetry was used to uncover the degree of similarity among individuals' ratings of one another. The results of these analyses showed the existence of the communication roles and contested collaboration and relationships between roles and individual and team performance (Sonnenwald & Lievrouw, 1997).

Thus quantitative data collection and analysis techniques tested and validated the taxonomy of communication roles and concept of contested collaboration. In this way, the facets of personality, matter, energy, space, and time were explored in an integrated series of studies that used multiple data collection and analysis techniques to investigate collaborative human information behavior in multiorganizational and multidisciplinary teams.

Consistency in the Formulation of Query Statements by Human Intermediaries

Increasingly, information seeking and searching are carried out in electronic environments using computer-based information retrieval (IR) systems. Searchers often can no longer walk to library shelves to browse and scan materials. Instead they must search for their document or topic interacting with a computer-based IR system, expressing (e.g., typing) their search request using words and syntax acceptable to the IR system. The system cannot respond before the searcher inputs a query. Therefore a query statement plays an important role in the search process. It is an expression of a search request in a form that can be processed by an IR system. It typically consists of one or more search terms that refer to search concepts and of search operators used to combine multiple search terms. Of course, query statements may change during the search process, but this does not mean that they are not needed.

The formulation of query statements is not an easy task, nor is it a task carried out consistently on various occasions. For any given search request, various searchers may choose to select different search concepts from the search request and describe those concepts with different search terms. In addition, the

same searcher may select different search concepts from the same search request and describe them with different search terms on different occasions. It is necessary to emphasize that "consistency" refers only to the degree of agreement in performing the same task on various occasions; it does not refer to the quality of performances.

Consistency is a phenomenon frequently studied in information studies in the area of information storage (indexing consistency) by counting consistency data points using various formulas. Consistency was studied in the formulation of query statements by considering consistency as a practice, aiming to understand its' nature by collecting multiple types of data (Iivonen, 1995a, 1995b, 1995c, 1995d; Iivonen & Sonnenwald, 1998). Although the focus of these studies was on the formulation of query statements (the energy facet), attention should also be given to searchers and their social networks (the personality facet), the type of information (i.e., search requests) that was processed, database and information systems (the matter facet), and the work environment (the space facet). It was understood that although the formulation of query statements can be seen as an episode and a task that is able to be completed, it is also a process that continues in a form of new tasks (new search requests) and reflects a searcher's expertise that grows as time goes on (the time facet).

In particular, the following research questions were addressed:

- What was the degree of intersearcher and intrasearcher consistency in the selection of search terms and search concepts from the same search requests?
- Which factors were lowering the intersearcher and intrasearcher term consistency and concepts consistency?
- Which kind of searchers are the most and least consistent searchers when intersearcher and intrasearcher consistency were considered.

The data collection methods used in these studies included quasiexperiments, interviews, and document analysis. Table 2 illustrates how these data are connected to the various facets in Ranganathan's system of knowledge organization.

The quasiexperiments were organized by test situations where 32 searchers with different backgrounds analyzed 12 search requests and formulated query statements from them for a search in a certain database. After 2 months the same searchers again analyzed eight of the same search requests and again formulated query statements for a search in the same database. After the test situations, the searchers were asked to explain their query statements. After the second test situation, the searchers were shown the query statements they had formulated in the first test situation, and they were asked to analyze and explain the differences in the query statements they had formulated.

The searchers were also interviewed to obtain information about the differences between searchers. Topics discussed in the interviews focused on work environments (e.g., the searcher's position in the organization), education and

training (e.g., the education and training the searcher had received in library and information science and in information retrieval), working experience (e.g., the searcher's duties in his or her current position), search experience (e.g., the searcher's experience in information retrieval in general and in this certain system in particular), and searchers' opinions and attitudes toward information searching. Interviews covered all facets.

Additional data for the study was collected from various documents to provide information about the organizational unit in which the study participants' worked, including the organizations' age, size, mission and goals, organizational structures, and formal job descriptions (the space facet). In addition, the descriptions of the database, information retrieval system, and vocabulary (matter) used in test situations were collected from documents.

To analyze the data, both quantitative and qualitative methods were used. The existence of consistency was examined by quantitative methods. Consistency data points were calculated using a specific formula and following specific rules. The significance of the differences in consistency was tested statistically. This was important for statistical inference because in this way it was possible to find whether observed differences were significant, occurred simply because of chance, or were caused by other factors. Qualitative analysis was needed to

TABLE 2
Facets Investigated in the Study of Query Formulation

Facets	*Data Collection Methods*
Personality	
Individual	Quasi-experiments, Interviews
Social Networks	Interviews
Matter	
Information and Information Resources	Quasi-experiments, Interviews, Documents
Access systems and Technology	Quasi-experiments, Interviews, Documents
Energy	
Problems/goals	Quasi-experiments, Interviews
Processes	Quasi-experiments, Interviews
Tasks	Quasi-experiments, Interviews
Space	
Work Space	Interviews, Documents
Organization	Interviews, Documents
Country/Geographic Unit	
Time	
Episode	Quasi-experiments
Interval	Quasi-experiments
Eon	Interviews

understand searchers' behavior and the reasons for the observed inconsistency. Qualitative analysis and interpretation of the searchers' explanations and interviews went from open coding to selective coding. The coding scheme was built by reading the searchers' explanations and interviews interpretatively. After the coding scheme was developed, the data were analyzed a second time to identify occurrences for each code. In addition, the illustrative data were used deliberately to convey the viewpoint of interviewees and to give a sense of reality to readers so that they could feel that they are inside the phenomenon.

A high degree of inconsistency in the formulation of query statements was found. Various searchers selected different search concepts and different search terms from the same search requests. Further, the same searcher formulated different query statements from the same search requests on various occasions. Intrasearcher consistency was, however, considerably higher than intersearcher consistency. Statistically significant ($p < .01$) differences in consistency data points were found according to the types of search requests (matter facet) and work environments (space facet). Factors lowering the consistency were understandable and related to searchers' expertise (personality facet) and preferences for different terminological styles and search strategies (energy facet). The groups of most and least consistent searchers were formed on the basis of both searchers' experience and social networks (personality facet) and organizational units (space facet).

Thus the phenomenon of inconsistency, which earlier was thought to be a real problem in human information behavior, became an understandable and normal phenomenon. Although searchers acted inconsistently, it does not mean that they acted badly. The searchers considered and explained their actions very clearly. Because of their different backgrounds and work environments, the decisions they made differed remarkably. By using multiple techniques in collecting and analyzing the data, we were able to show that the variety in query formulation is a real phenomenon that should be taken into account when designing information retrieval systems.

CONCLUSION

The framework for human information behavior research in this paper is based on the premise that human information behavior cannot be fully described, or understood, without considering the personality, matter, energy, space, and time facets. Human information behavior cannot be isolated from its wider contexts. Neither can it be assumed to repeat the same features always and everywhere. Because human information behavior has a multifaceted nature, research in human information behavior should consider these multiple facets. Therefore, the use of multiple data collection and analysis methods that are complementary may reveal more about human information behavior than the

use of any single method can reveal. Various methods should not be seen as alternatives or competitors but as methods that can contribute to the understanding of various aspects of human information behavior. By investigating and synthesizing multiple perspectives, it may be more likely to discover the shared experiences and perceptions of participants and, perhaps, more likely to discover and validate general patterns that may be constant over a variety of situations.

The framework may be useful as a tool in designing or planning research, comparing research results, and teaching in library and information studies. It assists researchers, practitioners, and students in understanding which categories should be covered and considered in studying human information behavior and which ones have been covered and considered. It can help researchers formulate research questions and provide some ideas about methods that could be used to collect data to answer those questions. In addition, the framework shows the variety of methods that can be used in studying these categories. Human information behavior is a multifaceted phenomenon and there is a need for a multifaceted research so that the facets can be recognized through the framework.

Typically, even in the field of library and information studies, researchers, practitioners, and students know and appreciate only a few research methods. Some level of parochialism can be found when individuals view the research from their own perspective and do not recognize other ways to carry out the research nor other aspects that should also be covered in the research. This kind of parochialism may have serious consequences when teaching LIS. The teachers may give a narrow picture of human information behavior to their students and a narrow picture of research methods.

Ranganathan's PMEST concept was developed for subject analysis of human knowledge and is well known in the field of classification research. Ranganathan's basic categories are identical to the categories that emerged in the metaanalysis of research in human information behavior reported in this paper. This is easy to understand. PMEST strives to support thinking, categorization, and analysis of the basic categories of the human knowledge. Human information behavior is intrinsically linked to human knowledge. Thus the PMEST categories provide tools to help design and interpret research in human information behavior and the context of human information behavior without losing the variety of the phenomenon by viewing it solely from a narrow point of view.

Other facets of human information behavior and data collection techniques may emerge in future research as being important. It cannot be claimed that the facets presented in this paper are complete, that is, the list includes all possible facets connected to human information behavior. Instead, we wish to emphasize that various facets should be considered when studying human information behavior. We found the facets useful and theoretically sustainable because of their basis in Ranganathan's work. However, we leave the door open to additional facets. The facets presented here are a starting point from which to reflect on and expand methodologic approaches used in information studies.

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