

Information Searching and Search Models

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Abstract

Key terms related to information searching and search models are defined. A historic context is provided to illustrate the evolution of the four main digital environments that users interact with in their search process to offer readers background information regarding the transition from manual information systems to computer-based information retrieval (IR) systems, as well as the transition from intermediary searching to end-user searching. Emphasis is placed on the review of different levels of information searching from search tactics/moves, search strategies, and usage patterns, to search models and associated factors in relation to task, user knowledge structure, IR system design, and social-organization context. Search models are further classified into two types, with one type illustrating information search process (ISP) and the other type emphasizing the factors that influence the process. In addition, unsolved problems and future research are discussed and suggested.

INTRODUCTION

The emergence of the Internet has created millions of end-users who search for information themselves. Information searching can be defined as users' purposive behaviors in finding relevant or useful information in their interactions with information retrieval (IR) systems. Despite their different foci, information searching can also be used as synonymous for IR, information-seeking, and information access.^[1] While information-seeking refers to purposive behavior involving users' interactions with either manual or computer-based information systems in order to satisfy their information goals, information-searching refers to the microlevel of behavior when interacting with different types of information systems.^[2] IR is also a broad concept similar to information seeking, but is more limited to users' interactions with computer-based information systems. Since research on information-seeking and IR has contributed significantly to research on information searching, some of the associated works are also reflected here.

Information searching can be characterized at different levels including tactics/moves, strategies, usage patterns, and models. Tactics or moves are the microlevel behaviors that users exhibit in their search process. Specifically, a tactic is a move that advances the search process. In some studies, a move can be defined narrowly by researchers. For example, a move is termed as any changes made in formulating a query.^[3] Searching strategies are a combination of tactics or moves. According to Bates,^[4] "A search strategy is a plan for the whole search, while a tactic is a move made to further a search (pp. 207)." A search strategy involves multiple dimensions, such as

intentions, resources, methods, and so on. Usage patterns identify patterns of query formulation and reformulation based on analysis of transaction logs submitted to electronic IR systems. Search models are illustrations of patterns of information searching and the search process. Some of the models also identify the factors that influence the search process.

Users and online IR systems are partners in the information search process (ISP). Online IR systems can be characterized as IR systems that allow remote access with searches conducted in real time.^[5] Users generally search information from four types of online IR systems: online databases, online public access catalogs (OPACs), Web search engines, and digital libraries. Information searching can be categorized into intermediary information searching and end-user information searching. In intermediary searching, information professionals serve as intermediaries between users and the IR system in the search process, whereas in end-user searching, users directly search for information themselves.

This entry starts with the definitions of key terminologies in the Introduction, and follows by providing the overview of the historical context portraying the history of the four digital environments. The focus of the entry is on the identification of levels of search strategies ranging from search tactics/moves, types and dimensions of search strategies and usage patterns to the factors that influence the selection and application of search strategies. More important, this entry presents ten search models that illustrate the dynamic search process and a variety of variables that define the search process. Finally, future research for information searching and search models is discussed.

HISTORICAL CONTEXT

In order to discuss information searching and search models, we have to first provide a historical context, in particular the evolution of the four major digital environments that users interact with. The emergence of online databases and OPACs indicates a new era for information searching from manual information systems to computer-based IR systems. The availability of OPACs and CD-ROM databases enabled users to search for information themselves. Later, the Web and the array of information resources to which it provided access made end-user searching of IR systems much more widely available. As partners of information searching, the development and evolution of online IR systems to some extent affects how users search for information. That is why it is important to offer a historical context for information searching before presenting a discussion of information searching and search models.

OPACs hold interrelated bibliographic data of collections of a library that can be searched directly by end users. In the 1960s, library automation projects started in university libraries. Computer-based library systems were implemented in large universities by commercial vendors in the 1970s. OPAC systems designed for public access started in the 1980s. Four generations of OPACs have evolved across time, from the first generation of OPACs that followed either online card catalog models emulating the familiar card catalog or Boolean searching models emulating online databases to the new generation of Web OPACs which incorporate advanced search features and new designs from other types of IR systems and allow users to search for information resources generated from libraries, publishers, and online vendors.

Online databases consist of full-text documents or citations and abstracts accessible via dial-up or other Internet services. Several dial-up services were offered in the 1960s, and in 1972 commercial online services, such as Dialog and ORBIT, started. Traditionally, online searchers were information professionals who acted as intermediaries between users and online databases. After the creation of the World Wide Web, online vendors began to design Web versions of online services to help end users to search for information themselves more easily. Characteristics of the new online database services include easy access, customization and interactivity.

The emergence of the Web in early 1990 enabled millions of users to search for information without the assistance of intermediaries. Web search engines allow users to mainly search for Web materials. Four types of search engines have been developed to enable users to accomplish different types of tasks:

- Web directories with hierarchically organized indexes facilitate users' browsing for information.
- Search engines with a database of sites assist users' searching for information.

- Meta-search engines permit users to search multiple search engines simultaneously.
- Specialized search engines create a database of sites for specific topic searching.

Many of the Web search engines also offer users the opportunity to search for multimedia information and personalize their search engines. Now, Web search engines also extend their services to full-text books and articles in addition to Web materials. The popularity of Web search engines influences the way that users interact with other types of online IR systems.

Digital libraries collect, organize, store and disseminate electronic resources in a variety of formats. The availability of online access to digital libraries began in the 1990s. Digital libraries allow users to search and use multimedia documents, and can be hosted by a variety of organizations and agencies, either for the general public or for a specific user group. Digital libraries also pose challenges for end users to interact with multimedia information in different interface designs without the same support as of physical libraries.

SEARCH TACTICS AND SEARCH MOVES

Research on information searching has focused on four levels: tactics/moves, strategies, usage patterns, and models. Tactics are moves that users apply in the search process. Different types of tactics play different roles in assisting users who are searching for information. Based on their functions in the ISP, information tactics can be classified into monitoring tactics, file structure tactics, search formulation tactics, and term tactics. While monitoring tactics and file structure tactics are tactics used to track the search and explore the file structure to find desired information, a source, or a file, search formulation tactics and term tactics are tactics applied to assist in the formulation and reformulation of searches as well as to help select and revise terms in search formulation.^[4] In addition to search tactics, idea tactics assist users in identifying new ideas and resolutions to problems in information searching. While idea generation tactics include think, brainstorm, meditate, etc., pattern-breaking tactics consist of catch, break, breach, and others.^[6] Focusing on topic management, knowledge-based search tactics are another type of tactic that broadens the topic scope, narrows the topic scope, and changes the topic scope.^[7]

Similar to tactics, search moves directly illustrate how users interact with online IR systems. Search moves in general relate to query formulation and reformulations. They can be classified based on whether the meaning of a query has changed. When operational moves that keep the meaning of query components remain unchanged, conceptual moves change the meaning of query components. Conceptual moves are highly associated with

search results. The objectives of these moves are to reduce the size of a retrieved set, enlarge the size of a retrieved set, or improve both precision and recall.^[3] Search moves can also be grouped depending on whether the moves are related to conceptual or physical moves. Cognitive moves refer to moves that users conceptually make in order to analyze terms or documents, while physical moves refer to moves that users make in order to use system features.^[8]

TYPES AND DIMENSIONS OF SEARCH STRATEGIES

Search strategies consist of combinations of tactics or moves, and can be characterized by types and dimensions. In online databases and OPAC environments, search strategies can be classified by different types: concept-oriented, system-oriented, interactive, plan and reactive strategies. Concept-oriented strategies refer to strategies that manipulate concepts of search topics. The majority of the most-cited search strategies belong to this type. Building-block, pearl-growing, successive-fractions, most-specific-facet-first, and lowest-postings-facet-first^[9] represent concept-oriented strategies. Unlike concept-oriented strategies, system-oriented strategies focus on making good use of different system features: the known-item instantiation strategy, the search-option heuristic strategy, the thesaurus-browsing strategy, and the screen-browsing strategy.^[10] The trial-and-error strategy is also a popularly applied strategy because people generally are not willing to use help features of IR systems.

Search strategies can also be defined by how and to what extent users interact with IR systems and information objects embedded in the systems. Search and browsing are the main strategies users employ when they interact with IR systems. Browsing strategies require more interactions than analytical search strategies.^[11] Active and reactive strategies specify another approach to classifying search strategies. By applying plan strategies, users make decisions about how to search for information before the first move, such as author, title, concepts, external support, system features, etc. By applying reactive strategies, users make decisions by following one move after another, such as focus shifts, search term relationships, error recovery and so on.^[12]

Search strategies in Web search engine environments have their own characteristics. Search strategies that concentrate on query reformulation were generated based on log analysis: specified, generalized, parallel, building-block, dynamic, multitasking, recurrent, and format reformulation.^[13–15] Some of them are similar to search strategies in online database environments, such as specified, generalized, and building-block, but others show unique characteristics of search strategies in the Web search engine environment, such as multitasking, recurrent,

dynamic, and others. In Web search engine environments, users sometimes perform different search tasks simultaneously; their searches are more dynamic, and they often apply the same search queries repeatedly. The Web environment also defines the unique design and features of the Web and Web searching. The ten problem-solving strategies^[16,17] represent search strategies in Web searching: surveying, double-checking, exploring, link-following, back- and forward-going, shortcut-seeking, engine-using, loyal engine-using, engine-seeking and metasearching.

In order to further analyze the structure of strategies, researchers have explored dimensions of information-seeking strategies. A multifaceted classification of information-seeking strategies was first developed based on four behavioral dimensions consisting of the goal of the interaction (learn, select), method of interaction (scan, search), mode of retrieval (recognize, specify), and types of resources interacted with (information, meta-information). Each type of information-seeking strategy corresponded to a specific prototype of dialogue structure.^[18,19] The underlying common dimensions of browsing—scanning (looking, identifying, selecting, and examining), resource (meta-information, whole object, and part of object), goal (locate, confirm, evaluate, keep up, learn, curiosity, and entertain), and object (specific item, common items, defined location, general, and none)—were identified to illustrate nine patterns of browsing.^[20] Integrating research and empirical studies in different digital environments, dimensions of information-seeking strategies are further illustrated by intentions, methods, entities and attributes of interactions. Twelve types of intentions include identify, learn, explore, create, modify, monitor, organize, access, keep records, evaluate, obtain and disseminate. Eleven types of methods consist of scan, manipulate, specify, track, select, survey, extract, compare, acquire, consult, and trial-and-error. While entities refer to what users intend to acquire or work on, attributes specify the traits/elements of these entities. Entities contain knowledge, concept/term, format, item/object/site, process/status, location, system and human. Attributes are associated with entities; for example, specific, common, general, and undefined are attributes of data/information. Different combinations of the four dimensions represent a variety of information-seeking strategies that people engage in within an ISP.^[21]

USAGE PATTERNS

Web searching adds new meaning to research on search strategies, in particular the analysis of transaction logs. Unlike studies on search strategies, usage patterns identified in Web search engine environments focus on patterns of query formulation and reformulation based on analysis of transaction logs submitted to search engines. Patterns of query formulation and reformulation in Web search

environments can be characterized in five ways: 1) short queries; 2) short sessions with minimum reformulations; 3) minimum use of operators and search modifiers, not always used correctly; 4) minimum viewing results; and 5) search topics ranging from entertainment, recreation, and sex to e-commerce.^[22–26] Log analysis is not limited to quantitative analysis; facets of query formulations were identified as well.

Usage patterns in different types of IR environments have also been compared. Both similarities and differences were identified. Short queries, short sessions, minimum view of search results, and similar unique queries were shown in Web search engine, Web page, and digital library environments. Search sessions vary in OPAC environments even though OPAC studies also exhibit short queries. More queries contain Boolean operators in digital library environments than in Web search engine environments.^[27,28] Wolfram and Xie^[29] defined the context of digital libraries as representing a hybrid of both “traditional” IR, using primarily bibliographic resources provided by database vendors, and “popular” IR, exemplified by public search systems available on the World Wide Web. Usage of online databases in digital libraries reveals that users’ search topics were close to online databases and digital libraries but their search behaviors were more similar to searching Web search engines. In general, users engage in more extensive searching in more traditional IR environments, such as OPAC and online database environments.

FACTORS AFFECTING INFORMATION SEARCHING

Information searching is affected by different types of factors, in which four main types determine the selection and application of different search strategies: 1) user goal and task; 2) user knowledge structure; 3) design of IR systems; and 4) the social and organizational context.

As to task, complexity of task and stages of task play major roles in influencing search strategies. Task complexity has systematic relationships with the types of information, information channels and sources needed. As the level of task complexity increases, more information channels and resources are required.^[30,31] The task stages, such as initiation, selection, exploration, formulation, collection, and presentation, on one hand, affect physical actions, cognitive thoughts, and affective feelings and appropriate tasks.^[32] On the other hand, task stages such as prefocus, formulation, and postfocus decide changes in search tactics, term choices, and types of information, as well as relevance criteria.^[33–36] When users move to a more focused stage, they apply more specified search terms, additional operators, and additional tactics. The types of information they search range from background information, theories and models to methods,

specific information and empirical research results. In addition, the familiarity of tasks, timeframe, and types of tasks affect how users plan and apply different types of information-seeking strategies in the IR process.^[37] Research has also demonstrated that different types of search tasks lead to the application of different types of information-seeking strategies.^[38–40]

Three types of knowledge are required for effective information searching: 1) IR knowledge; 2) domain knowledge; and 3) system knowledge. While domain knowledge helps users to develop an in-depth understanding of the search task and what they want, IR knowledge assists users to develop conceptual and procedural strategies.^[41] No doubt, experienced users apply better strategies and perform better than novice users in the ISP.^[42–45] Domain expertise was proved to affect search behaviors and strategies and search performance.^[46–49] Users in different disciplines have their unique characteristics in searching for information. For example, compared with scientists, humanities scholars engage in more searching for individual names, geographical and chronological terms, and unique terms in humanities.^[50] There are also intertwining relationships among different types of knowledge. For example, domain knowledge only influences search tactics of experienced searchers. Simultaneously, domain knowledge of users determines whether their retrieval knowledge has an impact on their search tactics.^[51] In addition to users’ knowledge structure, their cognitive abilities as part of personal information infrastructure, unavoidably, also control their search strategies.^[11] Cognitive styles and searching styles have been demonstrated as the main personal traits that influence search behavior and search performance.^[52–55] Simultaneously, cognitive styles and users’ knowledge structure are interrelated with search performance and search behavior. For example, cognitive styles have more impact on experienced users than on novice users in their interaction with Web search engines.^[56]

The design of IR systems no doubt affects users in their selections of search strategies. Interfaces, computational mechanisms, and information objects are the main components of IR systems that guide or impede users in their application of different search strategies. As partners of users in the ISP, IR systems—in particular the design of interfaces—could direct users to more or fewer applications of certain strategies. At the same time, the availability or unavailability of certain features determines whether users could engage in certain strategies. Finally, the information objects that users interact with and the outcomes of interactions might influence their choices of next strategy. Many studies conducted in the Text Retrieval Conferences (TRECs) have compared IR systems with different designs, and the results demonstrate that the design of IR systems makes significant differences in users’ application of search strategies and search performances. Researchers

have enhanced their IR systems based on the results of the evaluation studies.

The social-organizational context also defines the environment that user-system interactions take place. Mainly, the work environment influences how users determine their search strategies in the search process. Dimensions of a working place, such as the goals and constraints, priorities, general functions, work processes, and physical objects, in particular priorities, constraints, and business/work cycles have an impact on users' choices of search strategies.^[37,57] In addition, cultural dimensions shape how users interact with IR systems.^[58]

SEARCH MODELS

Because it is difficult to differentiate search models and retrieval models, in particular interactive IR models as well as some of the information-seeking models that involve search components and process, ten models in relation to information searching regardless of what terms are used by their original creators are presented here. These search models can be classified mainly into two types. The first type, which mainly illustrates ISPs, includes Ellis' model of information-seeking behaviors, Bates' berry-picking approach, and Kuhlthau's model of the ISP. The second type, which emphasizes the factors that influence the process, consists of Fidel and Soergel's conceptual framework for online bibliographic retrieval, Vakkari's theory of the task-based IR process, Ingwersen and Järvelin's cognitive model, Belkin's episode model of interaction with texts, Saracevic's stratified interaction model, Xie's planned-situational interactive IR model, and Wang, Hawk, and Tenopir's multidimensional model of user-Web interaction. In order to avoid repetition, some of the search models are briefly discussed because they are also presented in other entries.

Ellis' Model of Information-Seeking Behaviors

Ellis^[59,60] developed a behavioral model of the information-seeking behaviors of academic social scientists. This approach concentrates on the behavior instead of on cognitive activities. The six types of information-seeking characteristics are the key components of the model: 1) starting; 2) chaining; 3) browsing; 4) differencing; 5) monitoring; and 6) extracting. These characteristics cover the overall search process and indicate that users do engage in multiple types of information-seeking strategies. Ellis and Haugan^[61] further modeled the information-seeking patterns of engineers and research scientists in relation to their research activities in different phases and types of projects. Similar behavior patterns were identified from this group of users: surveying, chaining, monitoring, browsing, distinguishing, extracting, filtering and ending. Ellis' model starts a new behavior approach to identify information-seeking patterns

of users and cited widely by researchers who developed other search models.

Bates' Berry-Picking Approach

Continuing her work on search tactics, Bates^[62] illustrated the dynamic search process that searchers went through in the berry-picking approach (Fig. 1). It is one of the most cited approaches that not only identify the limitations of traditional IR models, but also characterize the complexity of the search process. It demonstrates that users engage in multiple information-seeking strategies in their search process. The berry-picking approach can be summarized with four characteristics: 1) searchers' queries evolve; 2) the search process is dynamic as people pick up berries instead of finding one retrieved set; 3) searchers apply multiple search strategies including footnote chasing, citation searching, examining journal runs, area scanning, performing subject and author searches in bibliographies and abstracting and indexing (A&I) services, and they shift their strategies during the search process; and 4) searchers access resources in different formats and content. The approach also outlines how to implement new search capabilities in the design of online search interfaces. Bates^[63] further developed the cascade model that describes several design layers, which have to be taken into account in the process of system implementation. Design decisions at each layer have a cascading impact on subsequent layers; therefore, the information content, its database structure, and retrievable elements are essential for effective IR. Bates' berry-picking approach sets up the foundation for interactive IR that considers search process as user-system interactions.

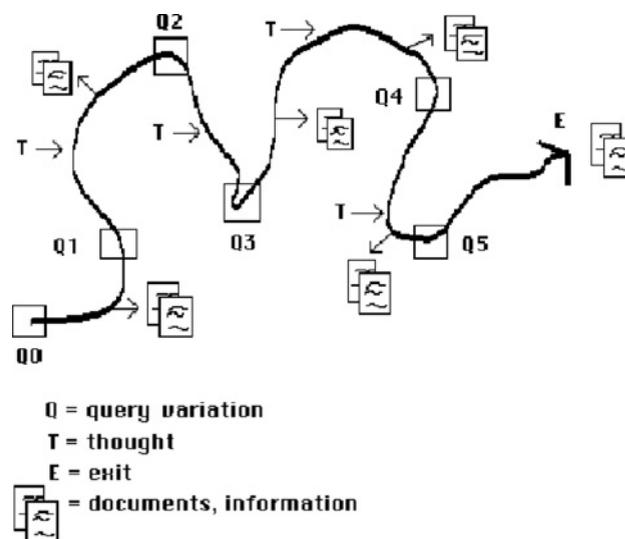


Fig. 1 Bates' berry-picking approach.

Source: From The design of browsing and berrypicking techniques for the online search interface, by M. Bates. In Online Rev., 13, 410, 1989.[62]

Kuhlthau's Model of the ISP

The ISP model was created based on a series of studies of users searching for information in different information-seeking situations. The ISP model consists of six stages of ISP with feelings shown, cognitive thoughts, and physical actions taken in each stage. The six stages comprise:

1. Initiation
2. Recognition of a need to search for information
3. Selection and identification of an appropriate topic or approach
4. Exploration of relevant information on the topic
5. Formulation of a more focused topic
6. Collection of relevant information
7. Presentation and summarization of search results

Correspondently, feelings common to each stage change from uncertainty to relief, satisfaction to disappointment; thoughts shift from general or vague to more focused; actions range from seeking background information to seeking focused information; and tasks transform from recognition to completion. The ISP model has been widely tested and validated in a variety of digital environments.^[33,34,64-66]

Fidel and Soergel's Conceptual Framework for Online Bibliographic Retrieval

Fidel and Soergel^[67] presented a conceptual framework for online bibliographic retrieval. The framework highlights the main factors that affect the search process. Eight elements of the search process and interactions were identified including the setting, the user, the request, the database, the search system, the searcher, the searcher process and the search outcome. The variables associated with these elements were systematically collected and analyzed: 1) the setting (e.g., organization's orientation, organization affiliations, subject area of the organization, organization mission, etc.); 2) the user (cost behavior, education, prior experience, attitude, etc.); 3) the request (degree of specificity, degree of difficulty, etc.); 4) the database (coverage, update frequency, thesauri availability, cross-reference listings, cost, etc.); 5) the search system (search aids, search support capabilities, search capabilities, etc.); 6) the searcher (cost consciousness, personality traits, cognitive factors, demographic variables, etc.); 7) the search process (interaction with the user, database selection, query formulation, termination of the search, etc.); and 8) the search outcome (quality of retrieved results, precision, recall, etc.). This framework identifies the main factors affecting online bibliographic retrieval, and suggests possible relationships among the variables related to the search process. Although it is created specifically for the online bibliographic retrieval environment, it can also be applied to other digital environments.

Vakkari's Theory of the Task-Based IR Process

Vakkari's theory of the task-based IR process (Fig. 2) considers the ISP as part of the task performance process. This theory is derived from a series of longitudinal studies that investigate students' information-seeking process in their research proposal-writing process for their master's theses.^[33-35,68,69] Based on the results of a series of studies, this model illustrates how the task performance process in particular stages of ISP influences the information sought, search tactics applied, terms chosen, operators used, relevance judgments assessed, and documents obtained and used. It further enhances Kuhlthau's model of the ISP in terms of the relationships between stages of task and types of information searched for, changes in search tactics and terms, as well as relevance judgments. This theory systematically presents how tasks have impact on the search process.

Ingwersen and Järvelin's Cognitive Model

Ingwersen and Järvelin^[70] developed a cognitive framework of interactive information-seeking, retrieval and behavioral processes (IS&R) (Fig. 3) based on Ingwersen's original work^[71,72] on the process of IR interaction. The new research framework places the cognitive actors or teams which bring their organizational, cultural, and social context to the interaction as the major component

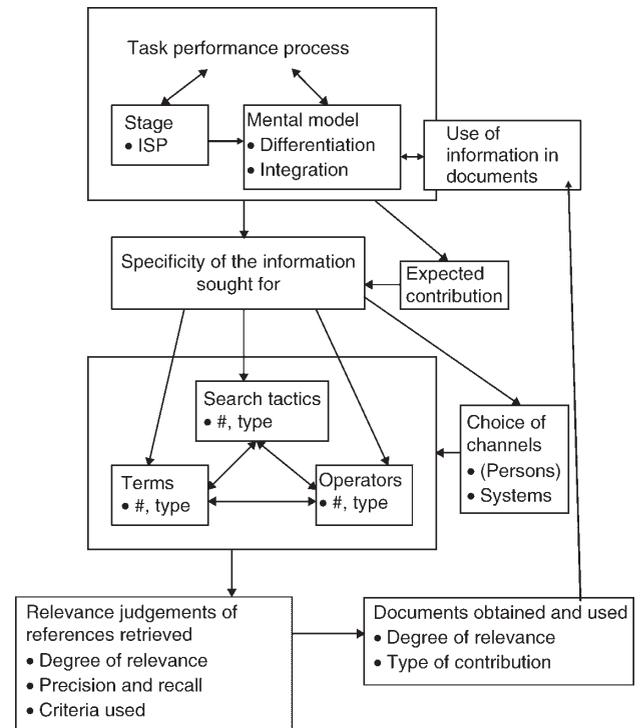


Fig. 2 Vakkari's theory of the task-based IR process. **Source:** From A theory of the task-based information retrieval process, by P. Vakkari.. In J. Doc., 57, 58, 2001.[69]

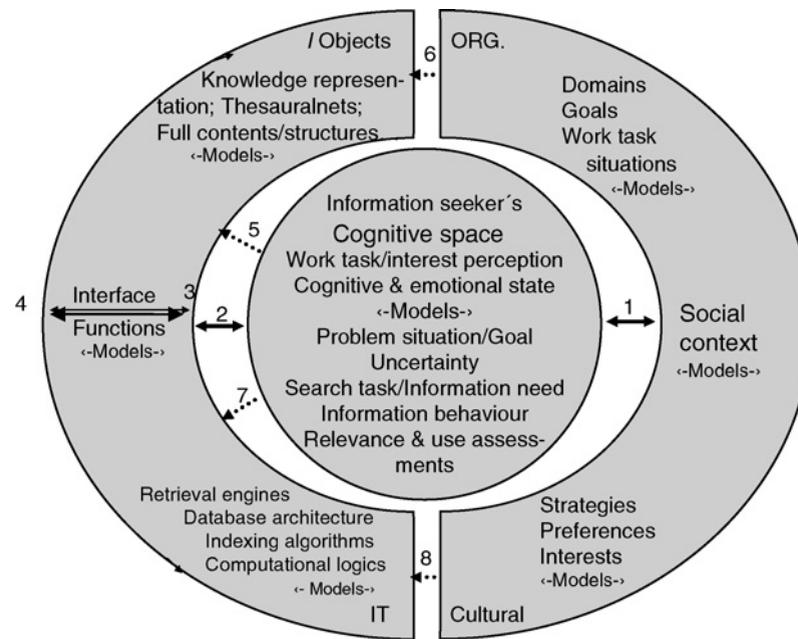


Fig. 3 Modified version of Ingwersen and Järvelin's complex cognitive framework of interactive IS&R.

Source: From *The Turn: Integration of Information Seeking and Retrieval in Context* (p. 274), by P. Ingwersen and K. Järvelin. In Springer, Heidelberg 2005. Modified by P. Ingwersen in 2007.[70]

of the model instead of the searcher as the center of the interaction. The cognitive actors or teams include creators of information objects, indexers, designers of interfaces, designers of retrieval mechanisms, gatekeepers, searchers, and communities representing different groups. While the first four arrows^[1-4] present the interaction process, the rest of the four arrows^[5-8] reflect the different types of generation and transformation of cognition or cognitive influence. An information seeker's cognitive space, interacting with both social context and IR systems, plays a central role. Interaction and perception are the central processes of the model. "Models" in each of the components reflect the perception of interpretation of their own contexts by any actor or component of the framework in a certain situation. All the participating cognitive structures are interrelated. This is one of the most comprehensive frameworks that reflect the dynamics and complexity of information-seeking and the retrieval process as well as associated factors.

Belkin's Episode Model of Interaction with Texts

Contrary to the traditional view of IR that people can specify their information needs and only engage in one type of information-seeking behavior, Belkin^[73] pointed out that IR is interaction with texts. He^[74] proposed the episode model interaction with texts (Fig. 4), in which users' interaction with texts is the central process of IR. Belkin and his associates^[18,19] further classified information-seeking strategies into four behavior dimensions (the goal of the interaction, method of interaction, mode of

retrieval, and type of resource interacted with) and designed a dialog-based IR system that supports different types of information-seeking strategies. In this model, users' goals and tasks are the driving force for IR whereas representation, comparison, navigation, presentation, and visualization are the processes that facilitate users' interaction with texts. This model offers a theoretical framework for understanding how users interact with texts by applying multiple information-seeking strategies, and it further suggests how to design interactive IR systems to support multiple information-seeking strategies.

Saracevic's Stratified Interaction Model

Saracevic^[75,76] proposed and enhanced the stratified interaction model (Fig. 5) in which interaction of the interplay among different levels of users and systems is the central component. While users engage in cognitive, affective, and situational levels of interaction, system involvement includes engineering, processing, and content-level. On the cognitive level, the interaction takes place between the cognitive structure of users and texts. On the affective level, users interact with intentions, beliefs, and motivation. On the situation level, users interact with tasks and problems that lead them to look for information. On the engineering level, the process level, and the content level, the hardware, software, and information resources are the foci for analysis, respectively. Users interact with IR systems via interfaces on the surface level by searching, browsing, navigating, organizing, and viewing search results, providing

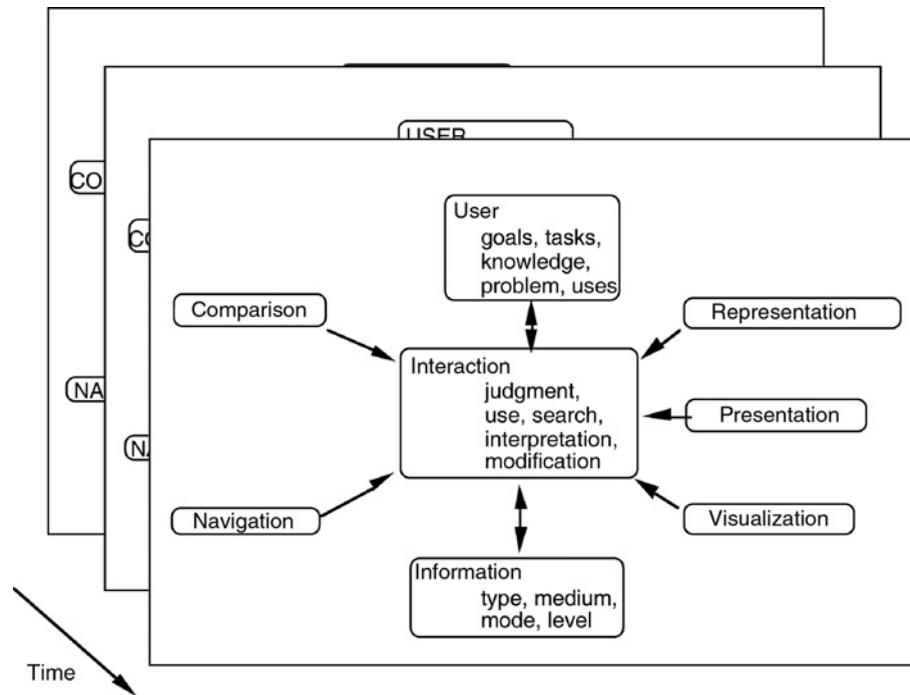


Fig. 4 Belkin's episode model of interaction with texts.

Source: From Intelligent information retrieval: Whose intelligence?, by N.J. Belkin. In ISI '96: Proceedings of the 5th International Symposium for Information Science (p. 29), Universtaetsverlag Konstanz, Konstanz, 1996.[74]

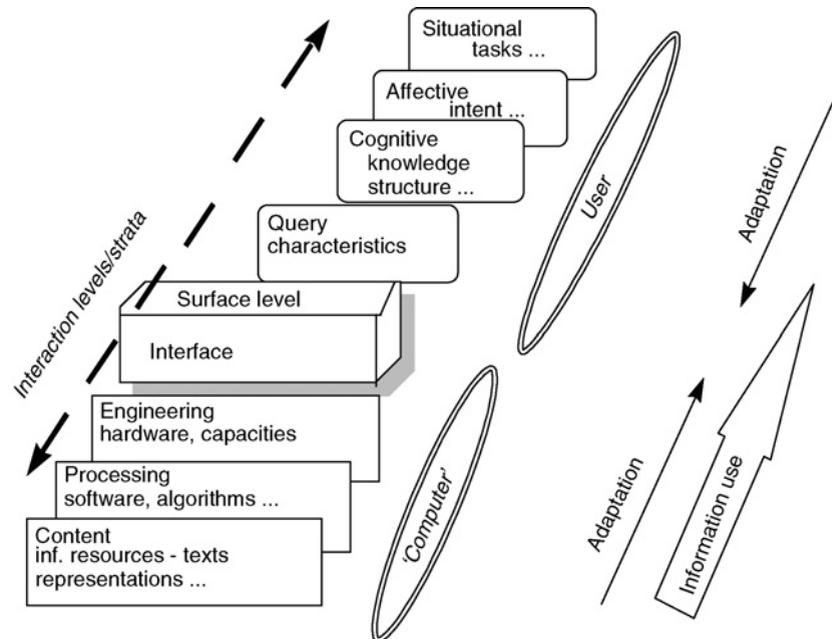


Fig. 5 Saracevic's stratified model of IR interaction.

Source: From The stratified model of information retrieval interaction: Extension and applications, by T. Saracevic. In Proceedings of the ASIS Annual Meeting (p. 316), Information Today, Medford, NJ, 1997.[76]

feedback, and other activities. Interactions not only take place at the surface level, but also occur at the deeper levels, which might also lead to changes at the surface level. The complexity and dynamic interaction process requires

changes and adaptations from both the user and system side. The main contribution of the stratified model is its identification of different levels of interactions from both the user and system side and their interplay.

Xie's Planned-Situational Interactive IR Model

Xie^[21] enhanced her previous work^[77,78] on the planned-situational interactive IR model derived from an empirical study. The planned-situational model of interactive IR (Fig. 6) is developed to illustrate how plans and situations codetermine users' applying and shifting different information-seeking strategies in their search process. User goal and task are the driving forces for people to look for information. Four levels of user goals are constructed: 1) long-term goal; 2) leading search goal; 3) current search goal; and 4) interactive intention. Dimensions of the work task (stages, timeframe, and nature) and search task (origination, type, and domain) are identified to characterize tasks. Higher levels of the goal/task impact lower levels of the goal/task. More important, levels of user goal and dimensions of tasks influence how users interact with IR systems. At the same time, information search requires users to apply different types of knowledge and skills into the search process. In addition, the social-organizational context defines the environment in which users interact with IR systems. Users and IR systems are the two partners of information searching. By interacting with the interfaces of IR systems, users interact with the information objects stored in these systems as well as with the computational mechanisms of the software and hardware of the systems.

Information-seeking strategies comprise interactive intentions and retrieval tactics, entities, and associated attributes. Planned and situational aspects codetermine the selection and shifts in information-seeking strategies. Three types of situations (routine, problematic, and disruptive) lead to different types of shifts in information-seeking strategies. In a routine situation, the situation can be determined sufficiently with the aid of habitual knowledge. In a problematic situation, after associating the elements of situations with his/her knowledge and plans, further clarification of the open elements of the situation is required. A third type of situation is a "disruptive situation," in which users do not encounter any problems, but they are distracted during the process of fulfilling their original current search goals/search tasks. The planned-situational model was tested and validated by empirical studies. This model not only identifies the macrolevel components for search and retrieval, but also uncovers shifts in information-seeking strategies and the factors that lead to the selection and shifts in information-seeking strategies at the micro-level.

Wang, Hawk, and Tenopir's Multidimensional Model of User-Web Interaction

Focusing on the Web environment, Wang, Hawk, and Tenopir^[17] proposed a multidimensional model of user-Web

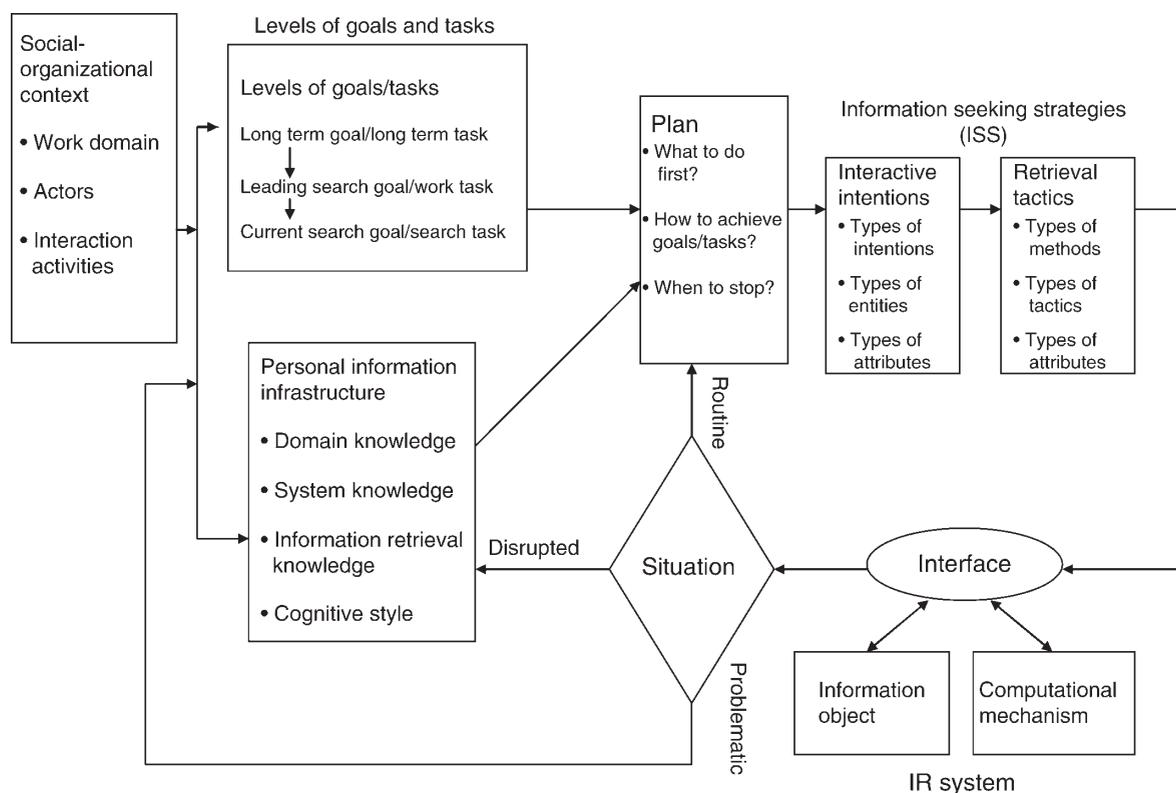


Fig. 6 Planned-situational interactive IR model.

Source: From *Interactive Information Retrieval in Digital Environments* (p. 216), by I. Xie. In IGI Publishing, Hershey, PA 2008.[21]

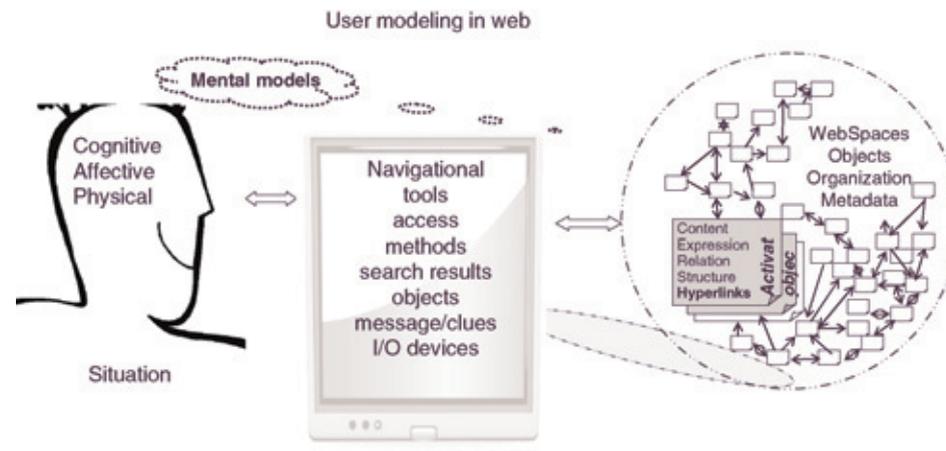


Fig. 7 Modified version of Wang, Hawk, and Tenopir’s multidimensional model of user–Web interaction in IR.
Source: From Users’ interaction with World Wide Web resources: An exploratory study using a holistic approach, by P. Wang, W. B. Hawk, and C. Tenopir. In *Information Processing & Management*, 36, p. 233. Modified by P. Wang 2008.[17]

interaction (Fig. 7). The model consists of the user, the interface, and the Web space. Among them, the user is the key component. Users are influenced by situation factors, cognitive behavior, affective state, and physical skills. The interface facilitates users’ interactions with Web spaces. Access methods, navigation tools, access results/objects, messages/clues, and input/output devices are the elements of the interface. The Web elements contain objects, activated objects, Web spaces, organization schemes, and meta-data. This model is further tested and validated by an exploratory study of graduate students’ interaction with a university Web site. They identified approximately ten problem-solving strategies. The findings show that cognitive factors define how users analyze questions, construct search statements and develop problem-solving strategies; affective factors affect how users adopt and use of strategies; and physical factors determine whether users can engage in efficient interactions. The multidimensional model of user–Web interaction defines how users search for information in the Web environment.

CONCLUSION

Information searching has evolved from searching for information using manual information systems to using electronic IR systems, as well as from intermediary search to end-user search. Recent research has revealed the limitation of traditional IR research: the assumption that information searching is static and people only formulate queries in their search process. Furthermore, research has shown that the ISP is a dynamic one in which people apply multiple types of search strategies. Different levels of information searching, from search tactics/moves to search strategies and usage patterns, have been identified, as well as factors associated with task, user knowledge structure, system design, and the social and organizational

context influencing the search process. More importantly, search models have been developed to illustrate either the dynamic search process or major elements that affect the search process. These models also offer suggestions for IR system enhancement and design.

Unsolved problems in research on information searching and search models still exist, however. First, although research on information searching helps reveal the nature of how people interact with different types of IR systems, very few findings of user studies have been applied to the design of IR systems. There is a big gap between user-oriented study and system-oriented design. More collaborative research is needed to incorporate and implement the design principles derived from user studies into IR system design and evaluation. Second, a variety of search models have been developed; the problem is that we may not be able to find a one-size-fits-all model to account for all of the issues in the search process. Further research needs to examine how to integrate different types of search models and identify what is still missing. Third, the newer digital environments call for the need to search for multimedia information and information in different languages. More research is needed to identify search patterns in multimedia and cross-language retrieval. Finally, in order to facilitate users’ easy adaptation to different digital environments, future research also needs to compare the similarities and differences of information searching in different digital environments and further transform research results into IR system design.

REFERENCES

1. Chu, H. *Information Representation and Retrieval in the Digital Age*; Information Today: Medford, NJ, 2003.
2. Wilson, T.D. Human information behaviour. *Inform. Sci.* **2000**, 3 (2), 49–56.

3. Fidel, R. Moves in online searching. *Online Rev.* **1985**, 9 (1), 61–74.
4. Bates, M.J. Information search tactics. *J. Am. Soc. Inform. Sci.* **1979**, 30 (4), 205–214.
5. Walker, G.; Janes, J. *Online Retrieval: A Dialogue of Theory and Practice*, 2nd Ed.; Libraries Unlimited: Englewood, CO, 1999.
6. Bates, M.J. Idea tactics. *J. Am. Soc. Inform. Sci.* **1979**, 30 (5), 280–289.
7. Shute, S.J.; Smith, P.J. Knowledge-based search tactics. *Inform. Process. Manage.* **1993**, 29 (1), 29–45.
8. Shiri, A.A.; Revie, C. The effects of topic complexity and familiarity on cognitive and physical moves in a thesaurus-enhanced search environment. *J. Inform. Sci.* **2003**, 29 (6), 517–526.
9. Markey, K.; Atherton, P. *ONTAP. Online Training and Practice Manual for ERIC Database Searchers*; ERIC Clearinghouse on Information Resources: Syracuse, NY, 1978.
10. Chen, H.; Dhar, V. Cognitive processes as a basis for intelligent retrieval system design. *Inform. Process. Manage.* **1991**, 27 (5), 405–432.
11. Marchionini, G. *Information-Seeking in Electronic Environments*; Cambridge University Press: Cambridge, 1995.
12. Soloman, P. Children's information retrieval behavior: A case analysis of an OPAC. *J. Am. Soc. Inform. Sci.* **1993**, 44 (5), 245–264.
13. Bruza, P.D.; Dennis, S. Query-reformulation on the Internet: Empirical data and the hyperindex search engine. In *RIAO 97: Conference Proceedings with Prototype and Operational Systems Demonstrations: Computer-Assisted Information Searching on Internet*, McGill University, Montreal, Quebec, Canada, 25th–27th June, 1997; RIAO 97, Ed.; CID: Paris, 1997; Vol. 1, 488–499.
14. Lau, T.; Horvitz, E. Patterns of search: Analyzing and modeling Web query refinement. In *Proceedings of the 7th International Conference on User Modeling Banff, Canada, June 1999*; Kay, J., Ed.; Springer-Wien: New York, 1999; 119–128.
15. Rieh, S.Y.; Xie, H. Analysis of multiple query reformulations on the web: The interactive information retrieval context. *Inform. Process. Manage.* **2006**, 42 (3), 751–768.
16. Hawk, W.B.; Wang, P. Users' interaction with the World Wide Web; problems and problem solving. In *Proceedings of the 62nd ASIS Annual Meeting 1999*, 36, 256–270.
17. Wang, P.; Hawk, W.B.; Tenopir, C. Users' interaction with World Wide Web resources: An exploratory study using a holistic approach. *Inform. Process. Manage.* **2000**, 36 (2), 229–251.
18. Belkin, N.J.; Marchetti, P.G.; Cool, C. BRAQUE: Design of an interface to support user interaction in information retrieval. *Inform. Process. Manage.* **1993**, 29 (3), 325–344.
19. Belkin, N.J.; Cool, C.; Stein, A.; Thiel, U. Cases, scripts and information seeking strategies: On the design of interactive information retrieval systems. *Expert Syst. Appl.* **1995**, 9 (3), 379–395.
20. Chang, S. *Toward a multidimensional framework for understanding browsing*; Unpublished doctoral dissertation, Rutgers University: New Brunswick, NJ, 1995.
21. Xie, I. *Interactive Information Retrieval in Digital Environments*; IGI Global Inc.: Hershey, PA, 2008.
22. Jansen, B.J.; Spink, A.; Saracevic, T. Real life, real users, and real needs: A study and analysis of user queries on the Web. *Inform. Process. Manage.* **2000**, 36 (2), 207–227.
23. Moukdad, H.; Large, A. Users' perceptions of the Web as revealed by transaction log analysis. *Online Inform. Rev.* **2001**, 25 (6), 349–359.
24. Spink, A.; Jansen, B.J. *Web Search: Public Searching of the Web*; Kluwer Academic Publishers: Boston, MA, 2004.
25. Spink, A.; Wolfram, D.; Jansen, B.J.; Saracevic, T. Searching the Web: The public and their queries. *J. Am. Soc. Inform. Sci.* **2001**, 52 (3), 226–234.
26. Silverstein, C.; Henzinger, M.; Marais, H.; Morica, M. Analysis of a very large Web search engine query log. *SIGIR Forum* **1999**, 33 (1), 6–12.
27. Jones, S.; Cunningham, S.J.; McNab, R.; Boddie, S. Human-computer interaction for digital libraries: A transaction log analysis of a digital library. *Int. J. Dig. Libr.* **2000**, 3 (2), 152–169.
28. Wang, P.; Berry, M.; Yang, Y. Mining longitudinal Web queries: Trends and patterns. *J. Am. Soc. Inform. Sci. Technol.* **2003**, 54 (8), 743–758.
29. Wolfram, D.; Xie, H. Traditional IR for Web users: A context for general audience digital libraries. *Inform. Process. Manage.* **2002**, 38 (5), 627–648.
30. Byström, K. Information and information sources in tasks of varying complexity. *J. Am. Soc. Inform. Sci. Technol.* **2002**, 53 (7), 581–591.
31. Byström, K.; Järvelin, K. Task complexity affects information-seeking and use. *Inform. Process. Manage.* **1995**, 31 (2), 191–213.
32. Kuhlthau, C.C. Inside the search process: Information seeking from the user's perspective. *J. Am. Soc. Inform. Sci.* **1991**, 42 (5), 361–371.
33. Vakkari, P. eCognition and changes of search terms and tactics during task performance: A longitudinal study. In *RIAO' 2000 Conference Proceedings, Content-Based Multimedia Information, Collège de France, Paris, France, April 12–14, 2000*; RIAO, Ed.; CID: Paris, 2000; Vol. 1, 894–907. http://www.info.uta.fi/vakkari/Vakkari_Tactics_RIAO2000.html (accessed July 15, 2008).
34. Vakkari, P. Relevance and contributory information types of searched documents in task performance. In *Proceedings of the 23rd Annual International ACM SIGIR Conference on Research and Development in Information Retrieval*, Belkin, N.J., Ingwersen, P., Leong, M.-K., Eds.; SIGIR forum; ACM Press: New York, 2000; Vol. 34, 2–9.
35. Vakkari, P.; Hakala, N. Changes in relevance criteria and problem stages in task performance. *J. Doc.* **2000**, 56, 540–562.
36. Vakkari, P.; Pennanen, M.; Serola, S. Changes of search terms and tactics while writing a research proposal. *Inform. Process. Manage.* **2003**, 39 (3), 445–463.
37. Xie, H. Understanding human-work domain interaction: Implications for the design of a corporate digital library. *J. Am. Soc. Inform. Sci. Technol.* **2006**, 57 (1), 128–143.
38. Bilal, D. Perspectives on children's navigation of the World Wide Web: Does the type of search task make a difference. *Online Inform. Rev.* **2002**, 26 (2), 108–177.
39. Ford, N.; Miller, D.; Moss, N. Web search strategies and retrieval effectiveness: An empirical study. *J. Doc.* **2002**, 58 (1), 30–48.

40. Schacter, J.; Chung, G.K.W.K.; Dorr, A. Children's Internet searching on complex problems: Performance and process analyses. *J. Am. Soc. Inform. Sci.* **1998**, *49* (9), 840–849.
41. Marchionini, G.; Dwiggin, S.; Katz, A.; Lin, X. Information seeking in full-text end-user-oriented search-systems—The roles of domain and search expertise. *Libr. Inform. Sci. Res.* **1993**, *15* (1), 35–69.
42. Howard, H. Measures that discriminate among online users with different training and experience. *Online Rev.* **1982**, *6* (4), 315–326.
43. Lazonder, A.W.; Biemans, H.J.A.; Wopereis, I.G.J.H. Differences between novice and experienced users in searching information on the World Wide Web. *J. Am. Soc. Inform. Sci.* **2000**, *51* (6), 576–581.
44. Siegfried, S.; Bates, M.J.; Wilde, D.M. A profile of end-user searching behavior by humanities scholars: The Getty online searching project (Rep. No. 2). *J. Am. Soc. Inform. Sci.* **1993**, *44* (5), 273–291.
45. Sutcliffe, A.G.; Ennis, M.; Watkinson, S.J. Empirical studies of end-user information searching. *J. Am. Soc. Inform. Sci.* **2000**, *51* (13), 1211–1231.
46. Bhavnani, S.K. Important cognitive components of domain-specific search knowledge. In *The Tenth Text REtrieval Conference, TREC-2001*, Voorhees, E.M., Harman, D.K., Eds.; Information Today: Medford, NJ, 2002; 571–578.
47. Drabentstott, K.M. Do nondomain experts enlist the strategies of domain experts? *J. Am. Soc. Inform. Sci. Technol.* **2003**, *54* (9), 836–854.
48. Dumais, S.T.; Belkin, N.J. The TREC interactive tracks: Putting the user into search. In *TREC: Experiment and Evaluation in Information Retrieval*; Voorhees, E.M., Harman, D.K., Eds.; The MIT Press: Cambridge, MA, 2005; 123–152.
49. Wildemuth, B.M. The effect of domain knowledge on search tactic formulation. *J. Am. Soc. Inform. Sci. Technol.* **2004**, *55* (3), 246–258.
50. Bates, M.J.; Wilde, D.N.; Siegfried, S. An analysis of search terminology used by humanities scholars: The Getty Online Searching Project report no. 1. *Libr. Quart.* **1993**, *63* (1), 1–39.
51. Hsieh-Yee, I. Effects of search experience and subject knowledge on the search tactics of novice and experienced searchers. *J. Am. Soc. Inform. Sci.* **1993**, *44* (3), 161–174.
52. Bellardo, T. What do we really know about online searchers? *Online Rev.* **1985**, *9* (3), 223–239.
53. Fenichel, C.H. Online searching: Measures that discriminate among users with different types of experience. *J. Am. Soc. Inform. Sci.* **1981**, *32* (1), 23–32.
54. Fidel, R. Searchers' selection of search keys: I. The selection routine. II. Controlled vocabulary or free-text searching. III. Searching styles. *J. Am. Soc. Inform. Sci.* **1991**, *42* (7), 490–527.
55. Ford, N.; Wilson, T.D.; Foster, A.; Ellis, D.; Spink, A. Information seeking and mediated searching. Part 4. Cognitive styles in information seeking. *J. Am. Soc. Inform. Sci. Technol.* **2002**, *53* (9), 728–735.
56. Palmquist, R.A.; Kim, K.S. Cognitive style and online search experience on Web search performance. *J. Am. Soc. Inform. Sci. Technol.* **2000**, *51* (6), 558–567.
57. Fidel, R.; Pejtersen, A.M. From information behavior research to the design of information systems: The cognitive work analysis framework. *Inform. Res.* **2004**, *10* (1). <http://informationr.net/ir/10-1/paper210.html> (accessed July 10, 2008).
58. Callahan, E. Interface design and culture. *Annu. Rev. Inform. Sci. Technol.* **2005**, *39*, 257–310.
59. Ellis, D. *The derivation of a behavioral model for information system design*; Unpublished doctoral dissertation, University of Sheffield: England, 1987.
60. Ellis, D. A behavioural approach to information retrieval system design. *J. Doc.* **1989**, *45* (3), 171–212.
61. Ellis, D.; Haugan, M. Modeling the information seeking patterns of engineers and research scientists in an industrial environment. *J. Doc.* **1997**, *53* (4), 384–403.
62. Bates, M.J. The design of browsing and berrypicking techniques for the online search interface. *Online Rev.* **1989**, *13* (5), 407–424.
63. Bates, M.M. The cascade of interactions in the digital library interface. *Inform. Process. Manage.* **2002**, *38* (3), 381–400.
64. Cole, C. Intelligent information retrieval: Part IV. Testing the timing of two information retrieval devices in a naturalistic setting. *Inform. Process. Manage.* **2001**, *37* (1), 163–182.
65. Hyldegard, J. Collaborative information behaviour: Exploring Kuhlthau's information search process model in a group-based educational setting. *Inform. Process. Manage.* **2006**, *42* (1), 276–298.
66. Kracker, J. Research anxiety and students' perceptions of research: An experiment: Part 1. Effect of teaching Kuhlthau's ISP model. *J. Am. Soc. Inform. Sci. Technol.* **2002**, *53* (4), 282–294.
67. Fidel, R.; Soergel, D. Factors affecting online bibliographic retrieval: A conceptual framework for research. *J. Am. Soc. Inform. Sci.* **1983**, *34* (3), 163–180.
68. Pennanen, M.; Vakkari, P. Students' conceptual structure, search process and outcome while preparing a research proposal. *J. Am. Soc. Inform. Sci.* **2003**, *54* (8), 759–770.
69. Vakkari, P. A theory of the task-based information retrieval process. *J. Docu.* **2001**, *57* (1), 44–60.
70. Ingwersen, P.; Järvelin, K. *The Turn: Integration of Information Seeking and Retrieval in Context*; Springer: Heidelberg, Germany, 2005.
71. Ingwersen, P. *Information Retrieval Interaction*; Taylor Graham: London, 1992.
72. Ingwersen, P. Cognitive perspectives of information retrieval interaction: Elements of a cognitive IR theory. *J. Docu.* **1996**, *52* (1), 3–50.
73. Belkin, N.J. Interaction with texts: Information retrieval as information seeking behavior. In *Information Retrieval '93: Von der Modellierung zur Anwendung*; Knorz, G., Krause, J., Womser-Hacker, C., Eds.; Universitätsverlag Konstanz: Konstanz, Germany, 1993; 55–66.
74. Belkin, N.J. Intelligent information retrieval: whose intelligence? In *Proceedings of the 5th International Symposium for Information Science (ISI '96)*; Humboldt-Universität zu Berlin, 17. -19. October 1996; Krause, J., Herfurth, M., Marx, J., Eds.; Universitätsverlag Konstanz: Konstanz, Germany, 1996; 25–31.

75. Saracevic, T. Modeling interaction in information retrieval (IR): A review and proposal. In Proceedings of the 59th ASIS Annual Meeting **1996**, 33, 3–9.
76. Saracevic, T. The stratified model of information retrieval interaction: Extension and applications. In Proceedings of the 60th ASIS Annual Meeting **1997**, 34, 313–327.
77. Xie, H. Shifts of interactive intentions and information-seeking strategies in interactive information retrieval. *J. Am. Soc. Informa. Sci.* **2000**, 51 (9), 841–857.
78. Xie, H. Patterns between interactive intentions and information-seeking strategies. *Inform. Process. Manage.* **2002**, 38 (1), 55–77.

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