New Directions in Cognitive Information Retrieval
TABLE OF CONTENTS

Preface ........................................................................................................ vii

I. Introduction

1. Introduction: New Directions in Cognitive Information Retrieval,
   *Amanda Spink and Charles Cole* ......................................................... 3

II. CIR Concepts

2. Interactive Information Retrieval: Bringing the User to a Selection State,
   *Charles Cole, Jamshid Beheshti, John E. Leide, and Andrew Large* ...... 13

3. Cognitive Overlaps along the Polyrepresentation Continuum,
   *Birger Larsen and Peter Ingwersen* .................................................. 43

4. Integrating Approaches to Relevance, *Ian Ruthven* ......................... 61

5. New Cognitive Directions, *Nigel Ford* .............................................. 81

III. CIR Processes

6. A Multitasking Framework for Cognitive Information Retrieval,
   *Amanda Spink and Charles Cole* ....................................................... 99

7. Explanation in Information Seeking and Retrieval,
   *Pertti Vakkari and Kalervo Järvelin* ................................................. 113

8. Towards An Alternative Information Retrieval System for Children,
   *Jamshid Beheshti, Leanne Bowler, Andrew Large, and Valerie Nesset* .................................................. 139

IV. CIR Techniques

10. Educational Knowledge Domain Visualizations: Tools to Navigate, Understand, and Internalize the Structure of Scholarly Knowledge and Expertise, Peter A. Hook and Katy Börner ........................................... 187

11. Learning and Training to Search, Wendy Lucas and Heikki Topi ........ 209

V. Conclusions

12. Conclusion and Further Research, Amanda Spink and Charles Cole ... 229

Biographies of Authors ................................................................. 235

Index .................................................................................................. 243
This book brings together chapters that present a range of new directions in theories, models and ideas about cognitive information retrieval (CIR). The aim of the book has been to draw out and examine new directions in CIR research. CIR is conceptualized as complex human information related human computer interaction processes that are embedded within an individual’s everyday social and life context. CIR is an important part of the human information condition and critical to the development of new approaches to the design of Web and IR systems. Subsequently, CIR is an interdisciplinary area of study that includes research from information science, computer science, human factors, cognitive science, human computer interaction and other information related disciplines.

In this book we provide cutting edge interdisciplinary theories, models and directions in CIR research. The book does not provide a history of the field of CIR, but includes papers that represent potentially significant and new research into many aspects of human information behavior (HIB). Emerging frameworks, models and theories are providing a more complex view of CIR that includes multitasking, relevance feedback, HIB and visualization techniques, and longitudinal process models. In particular, the book includes papers by some outstanding and often less established researchers, and chapters that often challenge the established views and paradigms of CIR research. The final chapter of the book provides an initial integrated framework and an overview of the key trends, theories and models emerging in the field.

In this book, we focused on collecting papers that broaden and deepen the framework for our understanding of CIR. The editors invited authors to contribute chapters that represented emerging research directions and ideas, in an effort to build a framework that extends beyond existing models and research, and provide new directions for further research. The editors and chapter authors are drawn from the international boundaries of CIR research, and this international spread contributed greatly to the interdisciplinary nature of the chapters.

The book represents a major intellectual endeavor for the editors. The first editor (Spink) is an information scientist who has worked with, taught and has researched various dimensions of CIR since 1980. The second editor (Cole) is an information scientist who has worked with, taught and researched in various areas of CIR research since 1994. The editors have collaborated extensively over the last six years on researching CIR, including empirical and theoretical studies, journal and conference papers, and special journal issues.

The book is organized into five sections. Section I provides a brief introduction to the interdisciplinary field of CIR. Section II includes chapters that provide a discussion of
key concepts for conceptualizing CIR, including relevance, cognitive, interactive and polyrepresentational approaches. Section III includes chapters that propose new approaches to the conceptualizing CIR processes within multitasking and HIB frameworks. Section IV includes chapters that discuss new CIR techniques, including relevance feedback, visualization and training frameworks. In Section V, the editors conclude the book by providing the range of new directions proposed in the chapters for further research.

Each section contains one or more chapters relating to the broader area of the section. Although each chapter is unique and comprehensive within its particular framework, and with its own reference list, the chapters are cross referenced where appropriate to illustrate how the different topics mesh together to form a broader expanse of CIR.

This book is intended as a resource for CIR researchers, educators, and practitioners. Researchers and students in the fields of information science, computer science, cognitive science, human factors and related disciplines, and scholars investigating CIR will all find the chapters presented here a valuable source of new ideas to help and further their respective research horizons. This book is also an appropriate text for undergraduate, graduate and doctoral level courses in areas of CIR and information science. Librarians, information professionals and others who provide information services will find this book useful for research-based insights into CIR. In addition, anyone who is interested in understanding the cognitive aspects of CIR will surely find this book a fascinating and enlightening read.

We greatly thank the chapter authors for their stimulating and ground breaking contributions. Many chapters represent the work of collaborations between researchers and their students. We also thank those who edited sections of the book, including Bhuva Narayan and Frances Alvarado-Albertorio from the University of Pittsburgh.

Amanda Spink, Faculty of Information Technology, Queensland University of Technology
Charles Cole, Graduate School of Library and Information Studies, McGill University
SECTION I

INTRODUCTION
CHAPTER 1

INTRODUCTION: NEW DIRECTIONS IN COGNITIVE INFORMATION RETRIEVAL

AMANDA SPINK
Queensland University of Technology, Australia

CHARLES COLE
McGill University

1. INTRODUCTION

Humans have used electronic information retrieval (IR) systems for more than 50 years as they evolved from experimental systems to full-scale Web search engines and digital libraries. The fields of library and information science (LIS), cognitive science, human factors and computer science have historically been the leading disciplines in conducting research that seeks to model human interaction with IR systems for all kinds of information related behaviors. As technology problems have been mastered, the theoretical and applied framework for studying human interaction with IR systems has evolved from systems-centered to more user-centered, or cognitive-centered approaches. However, cognitive information retrieval (CIR) research that focuses on user interaction with IR systems is still largely under-funded and is often not included at computing and systems design oriented conferences. But CIR-focused research continues, and there are signs that some IR systems designers in academia and the Web search business are realizing that user behavior research can provide valuable insights into systems design and evaluation.

The goal of our book is to provide an overview of new CIR research directions. This book does not provide a history of the research field of CIR. Instead, the book confronts new ways of looking at the human information condition with regard to our increasing need to interact with IR systems. The need has grown due to a number of factors, including the increased importance of information to more people in this information age. Also, IR was once considered document-oriented, but has now evolved to include multimedia, text, and other information objects. As a result, IR systems and their complexity have proliferated as users and user purposes for using them have also proliferated. Human interaction with IR systems can often be frustrating as people often lack an understanding of IR system functionality.

New more holistic directions in CIR are emerging that conceptualize human-IR system interaction at the human-computer interaction level (taking into account interface issues), the information behavior level (taking into account the role of IR system interaction in the total range of people’s information behaviors), and the
organizational/societal context (taking into account the information situation, task situation and problem situation of users when they use IR systems).

Researchers are thinking more broadly about information seekers rather than just as users of IR systems and the technical problems that may arise during the use.

In this book we also seek to highlight how the research field of CIR is more interdisciplinary and is now utilizing wider theories and models from sociology, psychology, communications, etc. The chapters in this book seek to stretch our understanding of CIR to incorporate questions of social and spatial factors, multitasking and non-linear dimensions, and relevance and learning issues.

The research in this book is above all conceptual, based on theory and model building. It is not descriptive (although descriptive studies of the user inform the conceptual research of many of the authors in this book).

Chapters in this book explore the conceptual operations, processes and information situation at the nexus between user and IR system, which informs the framework for conceptualizing the interaction between these two principal actors. The IR system is considered by the authors invited to contribute to this volume to be capable of assuming the role of an intermediary when the user utilizes an IR system to access information from the system’s database. The role of intermediary was traditionally played by the librarian, who brought to the table knowledge of both cognition and the situation of their users, frequently on an intuitive or experiential level.

Alternatively, how do we build these human-librarian capabilities into IR system design to make these systems truly interactive? Although the perspective of this book is user cognition—the IR system must elicit from the user a special kind of input, creating interfaces that direct and organize the user’s cognition so that the data accessed during the interaction has a true potential to be informational—our goal in developing this book has been to facilitate intellectual challenges to traditional IR system design assumptions and to champion new ideas.

These and other important research issues are explored in the following chapters.

2. BOOK OUTLINE

This book has five sections.

Section I: Chapter 1: Introduction

Chapter 1 provides an introduction to the book, setting out intentions and summaries of each chapter. We have divided up the chapters into sections, each with a theme.

Section II: CIR Concepts

Section 2 contains four chapters under the section title Concepts. These provide a definitional framework for the study of cognitive IR. Chapter 2 examines the concept of selection, which defines information use in cognitive IR interaction. Chapter 3 examines the concepts of polyrepresentation and the cognitive overlap of these representation states: the user’s task, problem situation, cognitive, and information need states. Chapter 4 analyzes the concept of relevance, suggesting a differentiated perspective on the
relevance concept be substituted for the unitary perspective currently used in IR design. And Chapter 5 examines the concepts of knowledge need and knowledge behavior as replacements for the concepts of information need and information behavior.

Chapter 2: Interactive Information Retrieval: Bringing the User to a Selection State—In Chapter 2, Cole, Beheshti, Leide and Large focus on the cognitive aspect of users as they interact with and react to environmental stimuli coming at them from the IR system. The authors closely examine other interactive IR models. Within a cognitive perspective, information need as a conceptual basis for the user in the interaction is problematic. Cole, Beheshti, Leide and Large then specify the terms and definitions of the user-system interaction they wish to examine in detail.

The authors seek to reconceptualize information need as the conceptual basis for user-system interaction. To this end, the interaction is represented by the authors as a series of interacting states: the user’s cognitive state, the user’s task or problem state, and the various need states for each task or problem that may arise during the user’s interaction with the IR system. In turn, the IR system presents the user with information stimuli that have the potential to align the user’s cognitive, task or information need states. The system stimulus message’s role in the interaction is to stimulate the user to make a selection, thus putting the user in a Selection State. When the user is in a Selection State, an information channel forms leading to information that if found, understood and integrated into the user’s knowledge structures, ends in an information process.

The last part of the chapter reports findings from a study of “selection” carried out in a naturalistic setting of history and psychology courses given at McGill University in 2003. The study tests the hypothesis that “selection” transforms the knowledge state of the subject. The study’s findings are that there are indications that this may be the case.

Chapter 3: Cognitive Overlaps Along the Polyrepresentation Continuum—Chapter 3 by Birger Larsen and Peter Ingwersen describes a user and document representation methodology that gives the IR system a fuller picture of the user and the document set than current simple request-based systems allow, based on the principle of polyrepresentation. For the user, the polyrepresentation consists of the user’s various concurrent information needs, emotional states, tasks, organizational obligations etc.—a multipronged representation of the user’s cognitive space. For the document set, the polyrepresentation consists of the citation links, thesaurus terms, selectors (e.g., journal name, etc.), indexers terms and author’s headings, captions, etc.—a multipronged representation of the document set. The polyrepresentations are then represented in the algorithm used by the system to match the user with the IR system database’s document set. The result is a cognitive overlap—of the user’s cognitive space and the information space of various configurations of document representations from various search systems.

The hypothesis upon which cognitive overlap is premised is that representations of different cognitive and functional origins point to a set of information objects in a particular seeking context. The resulting cognitive overlap—a sort of elaborate Venn diagram with an intersection in the overlap—presents more relevant information objects to the user in the polyrepresentation of the user’s cognitive space than each independent representation would be able to achieve. The potential of the cognitive overlap principle and polyrepresentation is therefore to serve as a common theoretical framework for research that integrates the information seeking or user perspective with the mainstream IR focus on designing and testing IR systems.
The authors outline research since the model was created that has tested various aspects of the model, particularly Larsen’s own boomerang effect (forward citation) application of the model. The authors then indicate strengths and weaknesses of the model. One issue in implementing the polyrepresentation model is whether to utilize best or exact matching methods to achieve the cognitive overlaps. The authors present a polyrepresentation continuum to conceptually organize the main challenge for future directions for research based on the principle of polyrepresentation: to further identify flexible matching methods that can generate high quality cognitive overlaps from a variety of representations.

Chapter 4: Integrating Approaches to Relevance—Chapter 4 by Ian Ruthven proposes a multidimensional perspective on the concept of relevance. The relevance concept currently forms the basis of correction feedback to the IR system, allowing the system to revise its matching algorithm so that it more accurately matches the real—as opposed to the initially expressed—information need of the user, represented in the interaction by the user’s query. We currently evaluate system performance according to the system’s ability to retrieve topically relevant documents; we therefore build systems for retrieving topically relevant documents. This strong view of relevance, Ruthven believes—with a single, objective reality to relevance based on topic—has been a major obstacle to the development of more naturalistic methods and systems.

Unfortunately, information science, with its concern for the user, and the dominant, system-oriented school in IR research, continue as independent research traditions. System-oriented IR research ignores the extensive, user-based frameworks developed by information science and information science underestimates the influence of IR systems and interfaces within the information seeking process.

The author proposes that the relevance concept can be changed to reconcile the two research traditions. This new, differentiated view of relevance can be measured as relationships between different entities; for example, relevance can be measured against surrogates or whole objects, against a human cognitive need or against a concrete search request. Therefore, rather than the current, single, binary definition of relevance, differentiated relevance requires only that we are clear about what definitions of relevance we are utilizing in any investigation.

Chapter 5: New Cognitive Directions—Chapter 5 by Nigel Ford introduces new terms into cognitive IR research: Knowledge need and knowledge behavior. These new terms are necessary because the old terms, information need leading to information behavior, cannot be specified by the user, while knowledge need is the sought after knowledge, which can be specified by the user. Information need has long been known to be a problematic concept (Belkin, Oddy, and Brooks, 1982; cf. also Cole, Beheshti, Leide and Large, this volume), because the information stimuli and information processes that will generate the sought after knowledge cannot be predicted by the user. The realization and specification of the knowledge need, along with the evaluation of information behavior in terms of its contribution to satisfying the knowledge need, are termed here knowledge behavior.

The essential problem for IR systems then becomes the transfer of knowledge from the IR system to the user of these systems. Knowledge is only transferable to other contexts if there is a rich mapping of elements. Also, the processes occurring in information processes and knowledge transfer involve two sides of the brain operating
in parallel. These two sides of the brain constitute two different components of human understanding, namely procedure-building and description-building. As a result, divergent information processing is needed in IR, not the present IR system which emphasizes convergent information processing.

The solution, Ford argues, is for the IR system to facilitate the user’s creation of the threshold of knowledge about a topic needed to facilitate the required information processes leading to knowledge transfer; users need to become their own practitioner-researchers. Ford suggests the IR system enable the creation of dynamic, interactive, multi-perspective and flexible “evidence maps” that can facilitate the user’s gradual build up of evidence into knowledge. The evidence maps would record the integration, cumulation, and disputation of—and other forms of interaction between—disparate information sources contained in the system’s knowledge base and the user’s gradually evolving knowledge of the topic through knowledge transfer from system to user.

Section III: CIR Processes

Section 3 contains three chapters under the section title Processes. These describe several processes involved in cognitive IR design and research practices. Chapter 6 concerns multitasking processes for cognitive IR design. Chapter 7 examines task process context variables that should be included in IR research. And Chapter 8 suggests that IR design should use as its guiding principle a social constructivism metaphor to encourage child learning when they use IR systems at home and at school.

Chapter 6: A Multitasking Framework for Cognitive Information Retrieval—Chapter 6 by Amanda Spink and Charles Cole analyzes user multitasking information behavior while the user is interacting with an IR system. Currently, IR systems require users to search sequentially and are largely designed to support limited types of searching based on specifying queries that select documents or Web sites to fulfill a single information task. However, IR system users naturally engage in multitasking while they are accessing information from an IR system. The users may begin their IR system interaction with multiple topics, or they may begin with a single topic and then develop additional topics during the search process. The authors define such behavior as natural, and examine possible mechanisms that enable the user to switch from one task to another while ostensibly engaged in accessing information from an IR system for one topic or task.

The authors begin the process of modeling multitasking within a cognitive IR framework, starting from Saracevic’s (1997) Stratified model of user-IR system interaction. They define the central problem as the user coordinating between various levels of problem identification, system problems, etc. for a single topic or task—on the level of searching the IR system—and the user’s wider thinking while interacting with the IR system—on the level of seeking information, which involves coordinating multiple search tasks and multiple topic tasks.

Chapter 7: Explanation in Information Seeking and Retrieval—In Chapter 7, Pertti Vakkari and Kalervo Järvelin examine task as a unifying variable in IR research. Presently, IR research originates from three separate fields: information science, computer science and contributions from the field of social science. However, the three
communities do not really communicate with each other, and use different methodologies. The authors examine these different methodologies in terms of dependent, independent and controlled for variables. The results of their examination suggest that the research communities within these three areas focus on different phenomena in terms of the independent and, in particular, the dependent variables used in the studies.

Because IR serves the goals of seeking, and information seeking primarily serves the goals of the user’s work task (or other interest), the authors suggest a possible area of reconciliation is the context or task for the user’s information search. The authors propose ways of increasing the overlap between the three competing research fields by enriching basic research frameworks with research variables related to the user’s work tasks as well as the user’s cultural activities/interests.

Vakkari and Järvelin examine two studies that can be seen to utilize a task-based approach to information seeking and retrieval research: a study investigating the use of electronic high school learning materials when answering high school exam questions, and an investigation that compares, via (among others) outcome variables, experts and novices engaged in business problem solving.

Chapter 8: Towards An Alternative Information Retrieval System for Children—
Chapter 8 by Beheshti, Bowler, Large and Nesset examines the complete picture of IR research for children, framing the discussion in four research traditions based on four different metaphors: behaviorism, information processing, cognitive constructivism and social constructivism. The information processing metaphor is still the dominant metaphor in IR design. According to this IR metaphor, information seekers could, it was assumed, negotiate through the universe of information with ease, once their own mental models matched those of the experts. External forces (external to the specifics of information searching), such as the user’s motivation, anxiety, or influences from the larger society were ignored.

In contrast to IR research and its information processing metaphor, in learning and information seeking (IS) research the current metaphor is social constructivism. Because of these different metaphor frameworks, the central problem the authors address in this chapter is reconciling the divide between IR and IS research regarding information seeking and searching of IR systems. Especially for children, information seeking and interaction with an IR system is done within a specific social context (social constructivism), while information processing at the individual level is about cognition (cognitive constructivism). The authors ask: How can the concept of a community of discourse be transferred into information technology where individuals seemingly work in solitude while they search for information? The question suggests a radical overturn of the way we think about IR, particularly for children.

The authors suggest a reconciliation research framework based on a social constructivism metaphor: the individual constructs learning in a particular social context. The affective factor, where the system gives children emotional and empathetic-tutoring dimensions, should be built into the interaction. The authors propose an alternative IR system for children which applies the concept of a Zone of Proximal Development—a social constructivist concept—to information seeking, an activity that is essentially conducted alone using an electronic data base. This alternative IR system involves implementing a supportive emotional context better adapted for children using learning-based IR systems.
Section IV: CIR Techniques

Section 4 contains three chapters under the section title Techniques. These describe the techniques involved in cognitive IR. Chapter 9 examines implicit relevance feedback techniques—the metrics used and assumptions researchers make about user intention from observing user behavior when they interact with IR systems. Chapter 10 describes visualization techniques for representing knowledge domains that facilitate knowledge integration for domain novice users of IR systems. Chapter 11 describes techniques of user search training that can be built into cognitive IR system design.

Chapter 9: Implicit Feedback: Using Behavior to Infer Relevance—Chapter 9 by Diane Kelly examines the techniques used by researchers to study the implicit relevance feedback behavior of users engaged in interacting with an IR system. The problem confronted by Kelly is users not engaging in the relevance feedback activities currently provided by IR systems. Implicit relevance feedback techniques may offer some solution to this problem. Implicit relevance feedback techniques unobtrusively obtain information about users, their needs and document preferences, by watching their natural interactions with systems.

The author refers to her own previous work which observed user behavior then classified the behavior into five categories describing the underlying intent of the observed behavior. The resulting five categories are: examine, retain, reference, annotate and create. Kelly then reviews the implicit relevance feedback research to illustrate how such studies have been conducted and how feedback has typically been measured and used. The author concludes that current studies of implicit feedback devote little time to exploring the validity and reliability of the metrics they employ, assuming that the metrics represent the actual behavior of interest (e.g. the length of time a document is displayed in the browser window is assumed by these studies to be equivalent to how long the user reads the document).

The chapter ends with an identification of the challenges for future implicit relevance feedback research.

Chapter 10. Educational Knowledge Domain Visualizations: Tools to Navigate, Understand, and Internalize the Structure of Scholarly Knowledge and Expertise—Chapter 10 by Peter Hook and Katy Börner analyzes various visual representation techniques for the purpose of improving the useability of Educational Knowledge Domain Visualizations (KDV’s). KDV’s visualize information spaces for specific topics or a broad range of topics, indicating to the user some sort of structure in a given information space. They can be incorporated into the IR system either at the front-end, as an overview of a topic space to assist the user in formulating an access point to the system’s database, or at the backend of the system in the results list. The visual representation of a topic or domain structure assists the user, especially the domain novice, in discerning the most relevant entry points into the information space, as well as facilitating user integration of the objective knowledge space represented by the KDV into the user’s subjective image of it. KDV’s facilitate the user’s search task of organizing the information search, information access, and management of his or her interaction with the IR system, and the information found in the system’s database.

The authors are primarily interested in how visualizing knowledge domains can facilitate user internalization of scholarly knowledge by taking advantage of the way
human vision and human spatial cognition work. From this point of view, the chapter outlines best-practice visualization design, then discusses and compares cartographic maps, including thematic maps, cognitive and concept maps, Knowledge Domain Visualizations, as well as Henry Beck’s 1933 famous metro map. Henry Beck’s 1933 redesign of the London Underground (subway) map was a revolutionary advancement in graphic design that has recently begun to serve as a model for the effective communication of system information spaces to domain novices and domain experts alike.

Chapter 11. Learning and Training to Search—In Chapter 11, Wendy Lucas and Heikki Topi describe techniques for training users in the information searching of IR systems. The authors set these search training techniques inside the broader perspective of information seeking. Different stages in the seeking process lead to different user cognitive processes, requiring different training models. Within each seeking stage, the user goes through a search process. Stage 1 in the Lucas and Topi model of the search process is the articulation of the user’s information need. Stage 2 is the conceptualization of the need as an executable query. Stage 3 is the formulation of the conceptual query for a given IR system. Stage 4 is entering the query into the search interface. And Stage 5 is the user understanding and interpreting the search results. Each stage requires different information search training procedures, which are, in turn, different depending on the stage of the seeking process the user is in at the time of the interaction with the IR system.

The second Lucas and Topi search training strategy is to gather user errors and then specifically train users on correcting these errors. Categories of user errors are conceptual knowledge errors, semantic knowledge errors, and technical knowledge errors (Sormunen and Pennanen, 2004). Examples of user errors from the Excite study of Spink, Wolfram, Jansen, and Saracevic (2001) are the infrequent use of Boolean operators and errors when the Boolean operators are used, such as errors in capitalization, the use of the ampersand instead of AND, etc.

Section V: Chapter 12: Conclusion and Further Research

Chapter 12 provides a conclusion and a discussion of further research.

REFERENCES


SECTION II

CIR CONCEPTS
CHAPTER 2

INTERACTIVE INFORMATION RETRIEVAL:
BRINGING THE USER TO A SELECTION STATE

CHARLES COLE, JAMSHID BEHESHTI, JOHN E. LEIDE,
AND ANDREW LARGE

Graduate School of Library and Information Studies, McGill University

1. INTRODUCTION

There have been various approaches to conceptualizing interactive information retrieval (IR), which can be generally divided into system and user approaches (Hearst, 1999; cf. also Spink, 1997). Both system and user approaches define user-system interaction in terms of the system and the user reacting to the actions or behaviors of the other: the system reacts to the user’s input; the user to the output of the system (Spink, 1997). In system approach models of the interaction, e.g., Moran (1981), “[T]he user initiates an action or operation and the system responds in some way which in turn leads the user to initiate another action and so on” (Beaulieu, 2000, p. 433). In its purest form, the system approach models the user as a reactive part of the interaction, with the system taking the lead (Bates, 1990). User approaches, on the other hand, in their purest form wish to insert a model of the user in all its socio-cognitive dimensions, to the extent that system designers consider such approaches impractical (Vakkari and Jarvelin, 2005, Chap. 7, this volume). The cognitive approach to IR interaction attempts to overcome this divide (Ruthven, 2005, Chap. 4, this volume; Vakkari and Jarvelin, 2005 Chap. 7, this volume) by representing the cognitive elements of both system designers and the user in the interaction model (Larsen and Ingwersen, 2005 Chap. 3, this volume).

There are cognitive approach researchers meeting in a central ground from both the system and user side. On the system side, are computer scientists employing cognitive research to design more effective IR systems from the point of view of the user’s task (Nathan, 1990; Fischer, Henninger, and Redmiles, 1991; O’Day and Jeffries, 1993; Russell et al., 1993; Kitajima and Polson, 1996; Terwilliger and Polson, 1997). On the user side are cognitive approach researchers applying methods, concepts and models from psychology to design systems that are more in tune with how users acquire information (e.g., Belkin, 1980; Ford (2005, Chap. 5, this volume); Ingwersen (Larsen and Ingwersen, 2005, Chap. 3, this volume); Saracevic, 1996; Vakkari (Vakkari and Jarvelin, 2005, Chap. 7, this volume)).

One cognitive meeting ground between user and system orientations is the conceptualization of the user-system interaction in terms of agents representing the user and the system acting on behalf of each actor in the transaction. The agents also have some sort of effect the one on the other that is not negligible. For example, Human-Computer Interaction (HCI) researcher Storrs (1994, p. 173) defines interaction as the
“exchange of information between participating agents through sets of information channels (interfaces) for the purpose of altering their states.”

The agent for the IR system is evolving but is centered on the results list, summaries of the results list, visualizations of the results list (Hook and Borner, 2005, this volume; Markoff, 2005), or any other representation of documents, Web sites, etc. contained in the system’s database and deemed by the system to match the user’s information need as it is represented to the system by the user’s agent in the transaction, the query. The user’s query represents the user’s information need in system approach IR research. However, this view of information need as the conceptual basis for the user’s agent in the user-system interaction has been questioned by cognitive approach research.

In this chapter, after describing the problem the cognitive approach has with information need, we propose a model of the user-system interaction that eliminates the user’s information need as the basis for the user’s initial request statement to the system. Instead, we reconceptualize the interaction using terms that are common to both user and system approaches to interactive IR design, such as state and selection. The term state, to represent some state of the user’s mind or thinking, has often been used in cognitive approach IR system research. Selection or selecting is an even older term in considering the user in the design of IR systems. In the pre-Internet, library environment, the trend towards open stacks and self-service in the late 19th century (Cutter, 1891–1893, p. 5) caused catalogers, indexers and classificationists to devise systems that assisted the user to (i) find, (ii) identify and (iii) select needed information while using the library’s IR system (the card catalog). The three objects as they were called (i.e., objectives) were expressly codified in 1876 by Cutter (1876/1904) in the introduction to his Cataloging Rules for a Dictionary Catalog.

(A 4th object, the obtaining object, was added in 1997 by the International Federation of Library Associations and Institutions (IFLA); and for the interactive technology era, Svenonius, 2000, has recently added a 5th, the navigation object. We discuss the 5th “navigation” object in Leide et al., 2003. The 2nd object, the collocation or identification object is discussed in Cole et al., 2005.)

The 3rd object, the selection object, is the subject of this chapter. In the next section, we discuss the weakness of information need as the conceptual basis for the user’s agent in IR interaction.

1.1. Information Need as a Basis for User’s Agent in Interaction

While both user and system approaches have the same goal—to maximize the utility to the user of the information found by the system—user oriented researchers have long believed (since for example, Belkin, Oddy, and Brooks, 1982) that the problem with current IR systems is their unidimensional model of the user as he or she is represented in the interaction between user and IR system, particularly the assumption that the user’s request statement to the system encapsulates the user’s information need.

In system approaches, the user’s agent in the interaction, the query, is assumed to be an apt representation of the user’s information need. Based on this assumption, modification of the need statement as a result of system feedback to the user (via interim results, thesauri, or other search aids offered by the system to help the user reformulate
the query) is to correct communication errors between user and system—i.e., to refine the match between the user’s information need and the system output. “Such reformulation strategies assume that the user’s information need is fixed throughout the search session, and a dialogue of sorts is taking place between the system and the user to help the system match the user’s fixed need” (O’Day and Jeffries, 1993, p. 440). Hearst (1999) and Ingwersen (1992) diagram this simplistic view of user-IR system interaction based on a unidimensional view of the user’s information need.

In this unidimensional, static view of information need, the user has a topic and knows what information he or she needs and types in topic elements as the request statement to the system. We currently evaluate system performance according to the system’s ability to retrieve topically relevant documents; we therefore build systems for retrieving topically relevant documents (Ruthven, 2005, Chap. 4, this volume).

Belkin and colleagues (Belkin et al., 1995) have long believed (Belkin, Oddy, and Brooks, 1982) that asking users to specify their information need in a query to the system is unrealistic. That in the real world, “Studies have shown that a searcher’s ability to get desired results is often very weak (Spink et al., 2001; Lucas and Topi, 2002). Key among these findings is the inability of searchers to choose correct search terms . . .” (Lucas and Topi, 2005 Chap. 11, this volume).

Rather than attempting to represent their information need in a query, user oriented researchers believe a more realistic approach is to bring the user’s problem or problematic situation into the interaction. The user’s problem situation has been an important Library and Information Science (LIS) concept beginning with Wersig (1971). It is primarily an information seeking concept as it includes derived user information behavior that is independent of the IR system—i.e., it is not purely an information search concept concerned only with user-system interface issues (Wilson, 1999; 2000).

By bringing the problem situation of the user into the user-system interaction, there is an immediate addition of a sociological perspective to the user’s agent in the transaction between user and system, particularly a consideration for the user’s task when seeking the information. The user’s problem situation also includes consideration of the organizational constraints on the user, and the importance of using the information found during the transaction to communicate a message via the user’s task to the organizational milieu governing successful performance of the task. The challenge in bringing these wider user concerns into the user-system interaction is how to ascertain then represent the problem situation in the user’s agent, a challenge taken up by user approaches to IR interaction since Belkin, Oddy, and Brook’s (1982) ASK concept (for an analysis of the ASK concept, cf. Cole et al. in press).

The general problem addressed in this chapter is to devise a user or cognitive approach to modeling the user’s problem situation so that it can form a substitute for information need as the user’s agent in user-system interaction. In Section 2, we review the literature on cognitive approach multidimensional models of user-system interaction, which consider the user’s problem situation in the interaction. In Section 3, we define terms for the proposed model, then diagram the model. In Section 4, we state the specific problem of the study which begins to test certain aspects of the model. In Section 5, we report the study. We end the chapter in Section 6 with conclusions and future directions for our research.
2. LITERATURE REVIEW: COGNITIVE IR’S MODELING OF THE USER’S AGENT

A number of multidimensional approaches to creating a viable agent for the user in the user-system interaction have been proposed by user oriented researchers (cf. Jansen, Spink, and Pedersen, 2005). An important distinction in these models is the difference between information search and seeking. The latter models set out to bring more general information behaviors of the user into the transaction, information behaviors that are conditioned by the user’s task, the purpose of the task, organisational constraints, etc. when he or she uses an IR system to seek information. Considerations of the user’s task and the wider sociological implications of the user’s search center on the decades old (since Wersig, 1971) information seeking term “problematic situation” or “problem situation.”

Beaulieu (2000) distinguishes information search interaction models from information seeking interaction models. Examples of information search-based models are Bates (1990), who focuses on the tactics and strategies of the user’s search of the IR system; and Lalmas and Ruthven (1999), who distil interaction to the system teaching the user how to conduct the search (cf. also, Lucas and Topi, 2005, Chap. 11, this volume). Examples of information seeking-based models are Efthimiadis and Robertson (1989), who divide user-system interaction into stages of the information seeking process; Vakkari and Jarvelin (2005, Chap. 7, this volume), who focus on the user’s situation or problem task in seeking information via an IR system; and Larsen and Ingwersen (2005, Chap. 3, this volume), who propose a polyrepresentation IR interaction model which includes a wider notion of the user’s problematic situation.

A certain number of multidimensional approaches to interaction propose operationalizing dimensions in terms of levels. Bates (1990), for example, divides interaction into four search activity levels: moves, tactics, stratagems and strategies. Spink and Cole (2005, Chap. 6, this volume) utilize Saracevic’s (1996) Stratified Model of user-system interaction in their of description of multitasking in cognitive IR (cf. also, Spink and Saracevic, 1997).

Saracevic’s Stratified Model of user-IR interaction posits a multidimensional view of user-IR system interaction, expanding the two actor traditional model of the user on one side and the computer IR system on the other, by dividing the user and computer into strata or levels. All the levels interact with each other and are affected or influenced by the interaction taking place between the other strata. The computer side is made up of four strata: the surface, engineering, processing and content levels; while the user side is made up of the surface, cognitive, situational and affective levels. The surface level interaction corresponds to the traditional model of user-IR system interaction described above, but also takes into account user strategies, tactics and other processes where the user explores the surface features of the IR system, or deals with system visualizations of the results list, for example, again on the surface or interface level of the computer side. The cognitive level, however, explores the user interacting with, for example, the content level of the computer side, assimilating texts cognitively. The situational level on the user side takes into account the task or problem situation of the user, which describes, along with the affective level on the user side, the panoply of motivations driving the user to seek information via the IR system.
Spink and Cole (2005, Chap. 6, this volume) in their model of multitasking during user-system interaction, conceptualize interaction between Saracevic’s Stratified Model levels as a human information coordinating behavior (HICB), a mechanism for task switching, for both search and information seeking tasks. An approach that emphasizes the affective level of the interaction is Beheshti et al., (2005, Chap. 8, this volume), who conceptualize a social constructivist IR system that adds emotional support to the user-system interaction for the design of IR systems for children users. Saracevic’s Stratified Model provides a much more complex view of user-IR system interaction than the traditional model of user-IR system interaction outlined in the Introduction above. Contrary to Beaulieu (2000), we place Saracevic’s Stratified Model of interaction in the seeking category because the user’s situational level is so strongly considered in the model.

A model that explicitly brings information seeking into the user-system interaction is Belkin et al.’s (1995) Information Seeking Strategies (ISS) Model of Interaction. The ISS Model is divided into four dimensions:

- Method of Interaction (search or scan)
- Goal of Interaction (learning or selecting)
- Mode of Retrieval (specification or recognition)
- Resource Considered (information or meta-information)

Any user’s ISS can be categorized depending on where it is placed on all four of the dimensions, giving (if dichotomous values) a total of 16 different ISSs. The strategies “arise from characteristics of the person’s problematic situation (Wersig, 1979); in particular, the user’s state of knowledge and information-seeking goals” (Belkin et al., 1995, p. 380). Within one search session, the user exhibits different ISSs “as [the] person’s problematic situation changes” (Belkin et al., 1995, p. 381).

The interaction between system and user in the ISS Model is conceived of as a dialog, with dialog states and action states, shown in a diagram of the “discourse act level” as circles and squares respectively. If for instance the user makes a request to the system for information, the user is in a request state (a circle). The system provides the information, it is accepted or rejected indicating a terminal state, or begins negotiation with the system indicating a dialog state.

The ISS Model terms “state” and “selection” are used by both user and system-oriented researchers in IR interaction. For system approach utilization of the word “selection” cf. Shannon, 1949; for system approach utilization of the word “state,” for example in the Turing machine, cf. Herken, 1995. Unusually for Belkin, the ISS Model slants usage of these terms in the direction of the system approach. The user approaches employ a broader definition, anchored in a multidimensional perspective of human information behavior (cf. Larsen and Ingwersen, 2005, Chap. 3, this volume). The next sections discuss user-approach definitions for these and other terms.

3. TERM DEFINITIONS

3.1. State

The user or cognitive approach utilization of the word “state” is a developing concept in cognitive information retrieval. Belkin, Oddy, and Brooks (1982) utilize the word
“state” in their central ASK concept (Anomalous States of Knowledge), to describe the states that lead users to seek information, which includes searching an IR system. Ingwersen (1996) uses the term cognitive state of the user, which includes interaction with the user’s state of uncertainty. In this theory, the user’s cognitive state is transformed through interaction with potential information objects from an IR system. Wilson (1999) also uses the term cognitive state (in addition to the user’s physiological and affective states); in the Wilson model, the cognitive, physiological and affective states change depending on the user’s stage of information seeking. Saracevic (1996) defines IR interaction’s purpose as to “affect” the user’s cognitive state: “The IR interaction is then a dialogue between the participants—user and ‘computer’—through an interface with the main purpose to affect the cognitive state of the user for effective use in connection with an application at hand” (Saracevic, 1996, p. 7).

The term “state” describes a static position of a person or thing (Oxford Dictionary, 1984), thus its utility for both use and system approaches. The state for the system is “predefined and fundamentally static” (Ingwersen, 1996, p. 7). However, to describe the user side of the interaction, the preferred term in user approaches because of its dynamic quality is “cognitive state,” which is defined as: “the state of the person’s cognitive processes” (WordWeb Online, http://www.wordwebonline.com).

The purpose of utilizing the term “cognitive state” is
- to replace the problematic term “information need,”
- to introduce a process conceptualization to the user’s agent, thus replacing information need which is static in the traditional model of user-system interaction, and
- to expand the conceptual sophistication of the user’s agent in the user-system interaction—i.e., the user’s query to the system—to include considerations of the user’s problematic situation.

As a result of this substitution of terms: “in addition to the traditional request formulation, supplementary separate paths for exploration and retrieval are made available: paths which otherwise might never be reached via the need-associated query versions alone” (Ingwersen, 1996, p. 39).

There is thus more than one cognitive process in the term “cognitive state.” Ingwersen (1996, p. 41), however, who also uses the term cognitive state, prefers using the term cognitive space to model the multitude of cognitive processes involved in the user-system interaction: “The concept of polyrepresentation of the user’s cognitive space involves representing not only the current (often topic) information need, but also (and more importantly) the underlying problem space, actual work task or interest, and the dominant work domain(s)” (Ingwersen, 1996, p. 41). As Ingwersen is a contributor to this volume (Larsen and Ingwersen, 2005, Chap. 3, this volume), we will briefly describe what is meant by “polyrepresentation of the user’s cognitive space.”

Chapter 3 of this volume by Birger Larsen and Peter Ingwersen describes a user representation methodology that gives the IR system a fuller picture of the user than current simple request-based systems allow, based on the principle of polyrepresentation. The polyrepresentation consists of the user’s various concurrent information needs, emotional states, tasks, organizational obligations etc.—a multipronged representation of the user’s cognitive space. During interaction between user and system, the system captures these representations via a request model builder (RMB)
The cognitive overlap of the polyrepresentation is then represented in the algorithm used by the system to match the user’s cognitive space with the IR system database’s document set, creating an information space for the particular user session.

The hypothesis upon which cognitive overlap is based is that representations of different cognitive and functional origins point to a set of information objects in a particular seeking context which is different than the information objects now pointed to in current systems by a user request statement alone, one based only on information need.

The RMB is derived from only three of the four cognitive structures inside the user’s cognitive space:

- the user’s information need statement,
- the user’s problem and goal statements,
- the user’s work-task/interest descriptions.

The three representations in the polyrepresentation representing the user’s cognitive space are “ANDed” together in the system’s matching algorithm, creating something like a Venn diagram. However, we are particularly interested in the four cognitive structures that feed into the three representations considered by the RMB in its formulation of the polyrepresentation of the user’s cognitive space:

- Information Need
- Problem Space
- Current Cognitive State
- Work-Task/Interest Domain

Note that the only structure in the above list which does not have a separate representation in the cognitive space polyrepresentation is the user’s Current Cognitive State.

We wish to further define then model the user’s Current Cognitive State. The Current Cognitive State (CCS) is defined by Larsen and Ingwersen (Chapter 3, this volume) as the “(limited) awareness or sense of what is desired.” This awareness is variable, changing throughout the user’s search session. The CCS is distinct from the user’s information need, which is the stated need. As all four cognitive structures are interconnected, the CCS is modeled in conjunction with the other three cognitive structures.

In our model (see below), we start with Larsen and Ingwersen’s statement that the three variable structures that constitute the user’s cognitive space “are easily affected by external input and/or thinking processes, while the work task/interest perception is set in a social context and may be more stable” (emphasis added). Also, “The problem space corresponds to Belkin’s ASK (Belkin, 1980; 1982) and is separated from the information need because the same problematic situation may give rise to several different information needs” (Larsen and Ingwersen, 2005, Chap. 3, this volume).

3.2. Current Cognitive State (CCS)

We begin modeling Current Cognitive State (CCS) by focusing on the Larsen and Ingwersen distinction between the user’s stated information need and the desired information. The latter only is included in their term CCS, but the other structures in the user’s cognitive space, including information need, are interconnected. Looked at this