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An Exploratory Study of IR Interaction for User Interface Design.

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Abstract

The thesis describe an exploratory and experimental evaluation of the user interface of the Dienst system, a WWW-based IR system implemented in a real-world online WWW setting. The study deals with two tasks: one evaluation task and one methodological task. Concerning the evaluation we investigate if the current user interface to the Dienst WWW-basedIR system provide sufficient support in order to conduct an information seeking task. We identify and describe characteristics of the user population. We also make suggestions for supporting user characteristics and needs in the user interface redesign

The methods are based on an interdisciplinary approach which combines both the IR interaction perspective and the user-centereddesign methods in HCI. The study implemented in an experimental real-world online WWW setting. We collect and analyze cognitive and statistical data from users performing an information seeking task using a combination of both qualitative (questionnaires) and quantitative (transaction logs) data collection methods.

Finally, based on our findings, we suggest important factors to be consideredand supported in the user interfacedesign.

Keywords : Information retrieval, interaction, user-oriented evaluation, information seeking strategies, cognition, interaction processes, user interface design

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Content

1. Introduction

With the rapid growth of distributed network-based information systems, together with tools like World-Wide Web (WWW) browsers, there has been an increasing spread and use of information. Through a more user-driven accessibility to information systems such as hypertext systems, users can search, browse and navigate within information spaces. This development constitutes a broad and diverse existence of both information systems and various user interfaces and functions. When offered via WWW, information retrieval (IR) systems often have large end-user populations. This is increasingly true for WWW-based hypertext systems, as well as OPACS and traditional online databases (such as the DIALOG collection of databases) with a WWW interface.

New and diverse ways and possibilities of interacting with different information systems are emerging. Together with the growing use of personal computers, this means that users, to a higher degree have to explore the vast and diverse information space themselves. The users' information needs, knowledge, experience and goals may vary and influence the information seeking process, and need to be identified and supported in the user interface design (Hansen and Karlgren 1996, p. 23). This situation presents a number of challenges in the field of information retrieval and Human-Computer Interaction (HCI) research. In order to understand these, we need to examine factors such as: how users interact with IR systems; how to design user interfaces for IR systems; different information seeking strategies and behaviours (Belkin et. al. 1995); the users' tasks and goals, individual differences (Borgman, 1989), cognitive abilities (Allen, 1994), and how to enhance users' navigation in the information space (Benyon and Höök, 1997).

We are constantly involved in various interactions with the environment through different communication mechanisms and processes. Information seeking is such a process, where users in different ways interact with the information environment. The main participants involved in the interactive information seeking process, are the user of the information, the information retrieval system, and the intermediary. By intermediary we generally mean a person or a mechanism (interface) which is placed between the information system and the user. In this study, we will refer to the interface as the intermediary. Generally, the intermediary has the task of guiding, supporting and transforming user's information problems or needs.

The traditional view of research into IR considers information seeking from a systems perspective, but research on IR techniques and tools solely cannot provide the understanding and knowledge of the interaction between the user and the IR system as recently proposed by Belkin et. al., (1995), Ingwersen (1992 and 1996) and Saracevic (1996).

Some critique against traditional methods used for evaluation of IR systems and users include:

- few studies on people performing real information seeking tasks with real information needs
- few studies are done in a real-world online IR setting
- few studies on what users really want to do and what they really do are rarely investigated
- from an IR perspective, there are very few examples that directly involve the user interface and what implications the user behaviour and information seeking strategies have on the user interface design

Recently, there has been a growing interest in interdisciplinary research approaches both in the information science area, especially within the IR field, and in the computer science area, within the HCI field (Hewins, 1990; Sugar, 1995; Koenemann and Belkin, 1996). One central issue within IR research today is how systems and intermediary mechanisms should be designed to support interactive information seeking tasks. This includes knowledge of the end-user's information seeking activities and design to support the user's interaction with the system (Belkin et. al., 1995). One of the goals within IR interaction research is then to improve the communication task between the participants in the IR environment. Other goals include investigating how different IR tools and techniques, user behaviour, user goals and tasks can be better adopted and support each other in an information seeking task. Library and information science research have a long tradition in conducting user and evaluation studies. Many of these studies have focused on measuring different retrieval techniques, methods and tools as solutions to the IR interaction problem. Studies in user behaviour and individual differences

(Egan, 1988; Borgman, 1989, Kuhlthau, 1993), and the intermediary/user interface in information retrieval (Marchionini, 1995, Brajnik et. al., 1996) have recently proved that this area is of great interest. Questions that have attracted growing interest are: How do we make a better adaptation to users' different preferences such as their tasks, goals, abilities, individual differences and how to support these in the design of the user interface?

In HCI research the main goal is to investigate and improve the usability of computer systems and the interaction between the user and the computer. Some of its research focus is evaluating and designing systems including user interfaces using different methods and techniques (see Norman, 1986, Jeffries et. al., 1991, Hix and Hartson, 1993, and Nielsen and Mack, 1994), as well as user and usability studies described by Dillon (1996). Recent studies have been focused on evaluation and design of adaptive user interfaces and hypermedia systems (e.g. Brusilovsky, 1996 and Höök, 1996b). See section 2.4.

Since information retrieval deal with human needs of information, we need to investigate user's needs, expectations, knowledge, as well as the IR system itself (in our case the user interface). To do this we apply a user-oriented approach influenced by the cognitive viewpoint proposed by Ingwersen (1996). As Allen (1996b) points out, there is a need to establish a link between research within IR and the design of user interfaces. A major recognized issue, is that the methods of evaluating information retrieval systems, under a long period, have been focused on precision and recall[1], but not on the *usability* of the user interface and how well users can accomplish their goals and tasks.

1.1 Research objective

For the study purpose, we used a networked (WWW) and distributed document database (Dienst), containing a set of Swedish Institute of Computer Science (SICS) research reports within the computer science area. The thesis describe an exploratory and experimental evaluation of the user interface of the Dienst system, a WWW-based IR system implemented in a real-world online WWW setting. The goal of our study are:

- to perform an experimental WWW-based evaluation of the information seeking interaction in an hypertext IR system and to investigate if the current user interface to the Dienst WWW-based IR system provide sufficient support in order to conduct an information seeking task
- to identify and describe characteristics of the user population
- to make suggestions for supporting user characteristics and needs in the user interface redesign

1.2 Research methods

The methods used in this thesis are based on an interdisciplinary approach which combines both the IR interaction perspective and the user-centered design methods in HCI. Within the HCI research area we could generally talk about three principles of a user-centered design: early focus on uses and tasks; empirical measurement of the application; and iterative design which includes design, test, and modification. Hix and Hartson (1993, pp. 148-149), describes the user-centered design and methods as the interaction development process principally based on user requirements, task analysis and users performing task. We will use a combination of questionnaires and database transaction log statistics to collect qualitative and quantitative data. For the evaluation task, we use a combination of data analyzing methods. The method has the following goal:

- to apply an interdisciplinary approach which combines both the IR interaction perspective and the user-centered design methods in HCI
- to implement the study in an experimental real-world online WWW setting
- to collect cognitive and statistical data from users performing an information seeking task using a combination of both qualitative (questionnaires) and quantitative (transaction logs) data collection methods
- to analyze collected data according to how users interact with the information system

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[1] Standard measures of IR performance. (Tague-Sutcliffe, 1995. p. 168).

These methods are further explained in more detail in chapter 4: Research Design and Methodology.

1.3 Research questions

Based on the background given, we believe that users have different preferences, knowledge and expectations and also that the satisfaction of the search outcome is influenced by these differences. We also believe that it is possible to observe and identify user's preferences and information seeking behavior. Since, in our experience, the current user interface to the Dienst database for SICS technical and research reports do not provide users (within the computer science domain) with sufficient support for their information seeking task, our purpose is then to investigate the following questions :

- Can WWW be used to conduct an experimental evaluation of the user interface of a hypertext IR system?
- What differences in user's preferences, knowledge and expectations can be observed?
- Which differences are there between different users and user groups concerning user's satisfaction with information seeking in the IR system?
- What are the requirements of our users? How do we support these differences and make better adaptations to them in the user interface design?

1.4 About this thesis

The thesis is organized as follows: Chapter 2 gives a theoretical background of information retrieval interaction, including the IR process, information seeking behaviour, IR interaction and user interface design and task analysis. Chapter 3 presents the Dienst system used in this study. Chapter 4 describes the research set-up, the WWW-based evaluation and data collection and analysis methods. In chapter 5 we discuss findings and results as well as present a task analysis. Chapter 6 takes up the user interface design problem and suggestions on how the user interface could be improved based on our results. Finally, chapter 7 contains concluding remarks and future work.

Limitations

Since this is an exploratory study, we will report, not only the results to our questions, but also other observations made during the investigation. This may lead to a "scattered view" of the thesis. Anyway, we think that it is important to report those findings. From our point of view, our exploratory study will also provide a framework for future study and research.

We will not evaluate the IR system from a traditional system point of view, that is, we do not intend to investigate measures like precision and recall. In this study we will not follow "closed" laboratory methods for the evaluation, that is, choosing our subjects by hand, giving them specific tasks. Issues like relevance feedback are mentioned as important factors, but not further elaborated in our study, and the performance evaluation of the distributed functions of the system are as well out of scope in our study.

In our thesis, we also mention the issue of navigation in hypermedia and hypertext spaces, which is a very important problems. Except from gathering data from one of the questions dealing with navigation, we will not elaborate on this subject. This should be a task in future work. Also, task analysis is a complex issue and in our study we use this technique to view and map the tasks the system offer the user. Future research could involve a comparison between the systems set of tasks and the tasks the user has to perform in order to accomplish their goals (to satisfy their information need).

It should also be noted that our mission is not to design a new user interface. Our study is concerned with extracting factors important *for* the user interface design. It is up to a design task to implement a new design based on the finding obtained in this study. This will be subject for future work.

2. Thesis Framework

Let us now turn to a description of some important concepts of the theoretical framework in which this particular study can be placed. Current research related to IR and information seeking interaction within information systems, shows a movement from text representations and their related techniques towards studies of the users and their information needs, behaviour and strategies, and interaction processes (e.g. Saracevic and Kantor, 1988; Kuhlthau, 1993; Marchionini, 1995). Studies of the interface and system design (e.g. Belkin, Marchetti and Cool, 1993; Brajnik, Mizarro and Tasso, 1996) are also of pertinence. Recently, we have seen examples of interdisciplinary research within the information science and the computer science areas (Koenemann and Belkin, 1996).

As we adopt a user-oriented and interdisciplinary approach to IR interaction and user interface design[2] we will combine theories and methodologies relevant to this study from both the information science field, especially within the areas of information retrieval interaction (Ingwersen, 1992, p. 12), information interaction, information seeking behaviour (Borgman, 1989), and evaluation of information systems, and also from the computer science field with, in particular HCI research, i.e. user interface design, user-centeredevaluation, task analysis (Norman, 1986; Diaper, 1989; and Nielsen, 1994). The characteristics of the users' information seeking behaviour, such as individual differences, user preferences and knowledge will help us to make a redesign of the user interface to better support the users.

2.1 Information Retrieval Interaction

We are constantly involved in various interactions with our environment and we interact through different communication mechanisms. Searching for information in an electronic environment is one such interactive process. As we are engaged in information seeking activities, there will be a number of individual and environmental factors and processes involved. The information seeking activity involves the critical problem of how we can support the user in finding her way to information. The user interface connects the user with the system and can be either human (e.g. an information specialist), or a mechanism (e.g. a user interface). In our study we will talk about the intermediary as a mechanism/device, e.g. an interface between the user and the system. Information retrieval interaction can be defined according to Ingwersen (1992, p. viii) :

> "...as the interactive communication processes that occur during the retrieval of information by involving *all* the major participants in IR, i.e. the user, the intermediary, and the IR system."

Since one of the main characteristics in an IR system is the level of interactivity, interaction can be thought of as being the level of control and support in making decisions in the various information seeking tasks and decisions throughout the interaction process.

Within the HCI research, Norman (1986, p. 38) has describedthe interaction activity between the user and the system as the "Gulf of Execution and Evaluation". According to Norman there is a discrepancy between the user's goals when using the system, and the physical system mechanisms :

> "The user of the system starts off with goals expressed in psychological terms. The system, however, presents its current state in physical terms. Goals and system state differ significantly in form and content, creating the Gulfs that need to be bridged if the system can be used" (Norman, 1986, p. 38)

It is important to investigate these differences in order to improve the design of the system and user interface.

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[2] Design of the medium through which the user and the system interact. The user interface is a front-end program that interacts between the user and the information system. One of its goals is to support the user performing effective tasks.

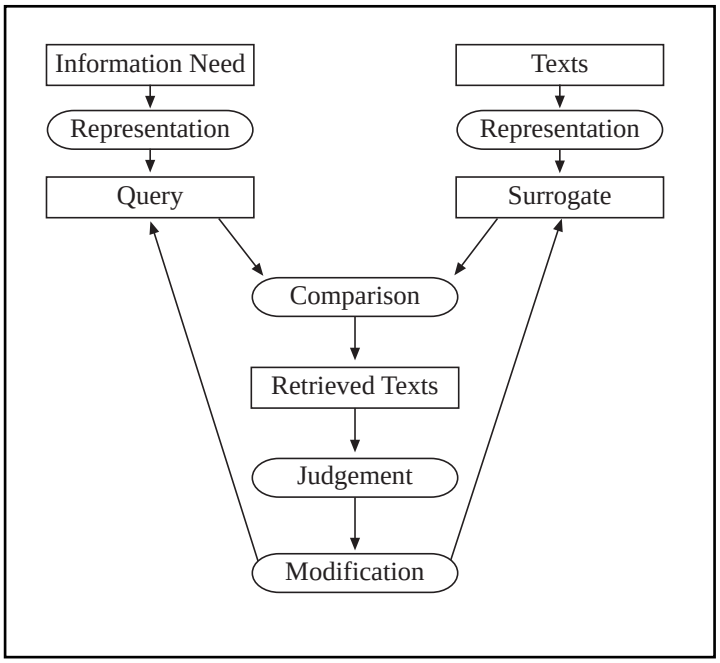
2.2 Information retrieval models.

A general view of an *information retrieval system* is that the IR system consists of a "device interposed between a potential user of information and the information collection itself" (Harter, 1986, p. 2). Generally, an IR system has three major components: *the database* which consists of the content and the physical container; *the communication channel or interface* between the user and the database, which has a physical component that facilitates interaction, and a conceptual component that gives the user guidelines on how to interact with the information structure and search mechanisms; and *the user* or information seeker (Marchionini, 1995). Thus the IR system can be seen as an interactive communication system (Meadow, 1994, p. 2).

The general goal of an IR system could be described as letting the user find information from a knowledge resource that enables the user to solve an information problem. Another view is described by Allen (1996a), where he defines an information system as an inter-linked system of entities that provides access to one or more bodies of knowledge and acts as a mechanism through which individuals can inform others or become informed themselves. Furthermore, he characterizes the information system as components that are linked to each other, defining the "collective purpose and function of the system" (Allen, 1996a, p. 4).

A general and traditional model of the *information retrieval* process involve components such as representation, storage, searching, finding, and presentation of potential information, desired by the information seeker (Ingwersen, 1992, p. 49 and Meadow, 1992, p. 2). A simplified version of the traditional IR model can be seen in Figure 1 below.

Figure 1. General model of information retrieval (from Henninger and Belkin, 1996, p. 33)



Within IR research, there has been attempts to develop and extend the traditional model into a model that take in account more interactive and cognitive[3] aspects of IR interaction.

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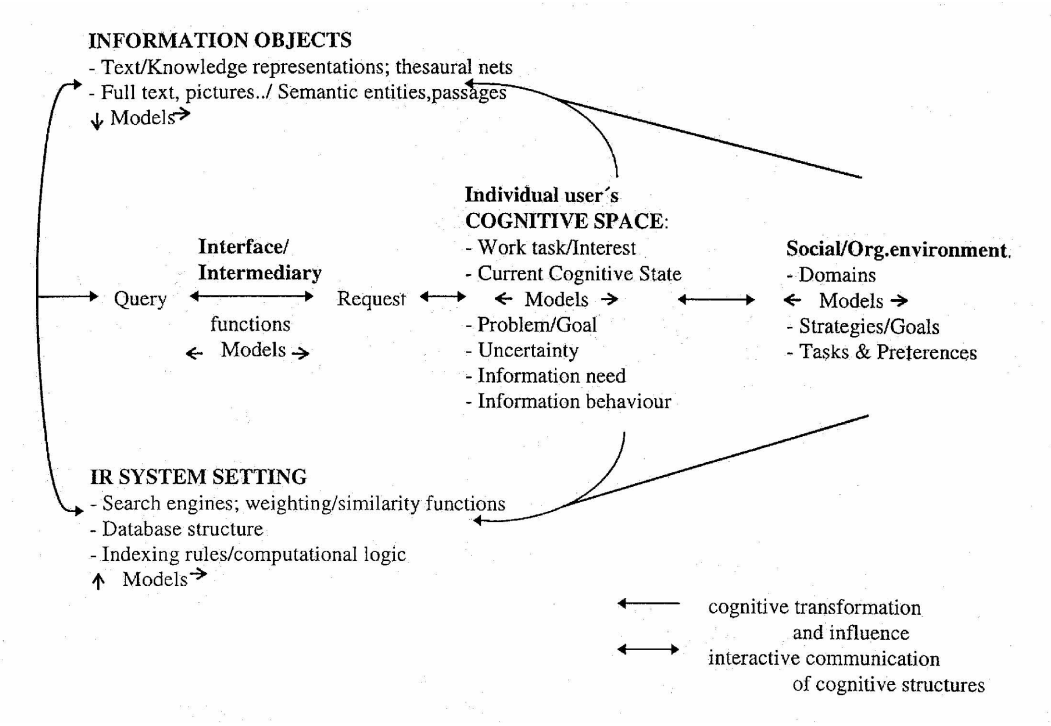
[3] Within the HCI field, cognitive psychology, cognitive science and human factors have influenced studies of human behaviour in order to understand the interaction between human and computer and to make better choices when designing systems. Within HCI this approach is called cognitive engineering. Within the IR interaction field, Ingwersen suggest that:

> "... cognitive IR models should view IR interactions as the interactions of various types of cognitive structures [...] generally understood as manifestations of human cognition, reflection or ideas. In IR they

The traditional IR model has mainly been concerned with improving the effectiveness of automatic searching techniques, such as precision and recall, and has been criticized for not taking issues like cognitive and interactive aspects into consideration (Saracevic, 1995 and 1996, p. 207; Ingwersen, 1996, p.13). Several research attempts, within the IR interaction, have been made to extend the limitation of the traditional IR model by trying to develop an understanding of and support for IR interaction in a broader sense. A very interesting extended model, is Peter Ingwersen's *cognitive model of IR interaction* (1992; further elaborated in Ingwersen, 1996), (see Figure 2). Our study will use this model as a point-of-departure. In this model, the IR interaction is viewed as a set of cognitive processes.

Figure 2. Cognitive model of IR interaction (Ingwersen, 1996, p. 9)



These processes involve system characteristics (representational and retrieval techniques), the user's situational characteristics and the functionalities of the intermediary. Ingwersen makes a very interesting point when he says that different cognitive (knowledge) structures are involved in the IR interaction and the information space (Ingwersen, 1992, p. 134-146). Users do not only interact with systems, but also with texts and objects, indexing rules and the user interface. This view has been elaborated further by Ingwersen (1992) where an IR system is understood as an information (retrieval) system that involves interactive processes between information objects, the system setting and the user (environment), when an information seeking activity is initiated. Recently, there has been additional research on the IR process, focusing on human behaviour and information seeking activities. A theoretical model, called *the episode model* (see chapter 2.2.2) has been proposed by Belkin et al. (1995), and yet another one has recently been proposed by Saracevic (1996), suggesting a *stratified model of IR interaction*.

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take the form of transformations generated by a variety of different intentionalities and cognitive origins." (Ingwersen and Willett, 1997).

2.2.1 Information retrieval process, behaviour and strategies

When users want to find information, they consult an information knowledge resource, and initiate a *communication process* (Meadow, 1992, p. 2). In IR interaction an interactive communication process takes place between the different participants during an information retrieval activity. These participants are *the user* with knowledge, tasks and goals; *the IR system* which consists of the knowledge resource (content) and the *intermediary* (human or machine) which acts between the user and the IR system. There is also the IR system setting containing the hardware and the software. A basic information seeking process can be described as follows: the user have some kind of information need that needs to be satisfied. There can be several reasons for this underlying need. The user identifies resources and approaches for example an IR system (like the one in our study). The user now tries to express the information need and an interactive process starts. when deciding to approach a knowledge resource (with an information need), the user approaches an information retrieval system (knowledge resource) and an interactive process starts. This interaction between the user and the system will take place by way of a human intermediary or a mechanism such as a graphical user interface. The purpose of an information seeking activity is to change the information seeker's state of knowledge in some way. Ingwersen suggests that the information concept then has two requirements:

> "... on the one hand information being the result of a transformation of a generator's knowledge structures [...]; on the other hand being something which, when perceived, affects and transforms the recipient's state of knowledge." (1992, p. 228)

During this communication, which includes a user with an information need and a retrieval component, the user has the possibility of finding information from the knowledge resource. The IR process itself could also be categorized in several stages or levels. Marchionini uses the term information seeking (1995, pp. 5-9), when talking about searching for information, suggesting that information seeking connotes a cognitive process of acquiring knowledge. This interpretation will also be used in our study. Later, Marchionini describes information seeking as a dynamic and action-oriented process, where a set of processes are involved such as: information problem recognition; information problem definition and understanding; search system selection (depending on previous experience with the domain, problem formulation, search, and cognitive abilities); query formulation (mapping of the task with the information system selected); search execution (dependent on the information seeker's mental model of the system); result examination; information extraction (reading, scanning, copying and storing); information search reflection, iteration and completion (Marchionini, 1995, pp. 49-60). These tasks or processes are all important for the interface (re)design. Another model, presented by Kuhlthua (1993), describes the tasks that are involved in the information seeking process from a psychological view and perspective: the affective (feelings), the cognitive (thoughts), and the physical (actions) activities made in such a process. Kuhlthua describe six stages of the search process: the task initiation (information need recognition); topic selection; pre-focus exploration (information inspection); focus formulation (topic decision); information collection (information gathering and selection); and search closure (recheck of problem and search results), (ibid, pp. 41-53).

Within an information seeking situation, people use different *strategies* to solve an information problem and to accomplish their goal. Belkin (1980) proposed a (theoretical) model where the information user is concerned with solving a problem. This model makes the assumption that the user has a *problematic situation*, which means that there exists some kind of need for information. Belkin calls this the user's "*Anomalous State of Knowledge* "(ASK) (Belkin, 1980, p. 135) The information seeking action then involves a process where the user must articulate a search request.

An *information need* (or ASK) initiates a person to perform an *information seeking task* and thus activates *information seeking behaviour and strategies.* When performing an information seeking task, this activity is dependent on several factors, such as the information seeker or user, the tasks and goals, the information system, the domain, and the satisfaction with search results (Marchionini, 1995, pp. pp. 32-49). As we could see in Figure 2, Ingwersen also recognizes different aspects that are involved in the IR interaction, which can be viewed as cognitive processes (Ingwersen, 1996, pp. 9-10).

Belkin et al (1995) proposed a scheme for classifying information seeking strategies (ISS) according to a number of behavioural dimensions. In the *episode model* (Belkin et. al. 1995, p. 380), the user's interaction with the information system is the central process which should be understood *as* interaction, and then, especially as human-computer interaction.

> "...the information seeking behaviour is characterizedby movement from one strategy to another within the course of a single information seeking episode, ..." (Belkin et. al., 1995, p. 381).

These interactions between the user and the different IR system components depend, according to Belkin, on the user's characteristics, such as the user's state of knowledge and tasks and goals. Based on earlier studies, Belkin et. al. (1990, and further elaborated in Belkin et. al., 1995, pp. 380-381) proposed a model of information seeking behaviour consisting of four dimensions (Table 1), and a model of 16 information seeking strategies (ISSs).

Table 1. Dimensions of information-seeking strategies. (Belkin et al. 1995, p. 380)

	Method of Interaction	
scanning	<---------->	searching
	Goal of Interaction	
learning	<---------->	selecting
	Mode of Retrieval	
recognition	<---------->	specification
	Resource Considered	
information	<---------->	meta-information

According to Belkin, the user moves between these different strategies. Belkin also proposed that this human-computer interaction in information seeking strategies can be modeled as an IR interaction dialogue. The model of IR system design, in this way, could provide the means of supporting users in their information seeking strategies and behaviours.

Within the IR research area, there are numerous studies on information behaviours that have examined the user's information needs, tasks, goals, knowledge and experience, to gain understanding on how people perform information seeking activities. This has also been studied within the HCI field where the design of tools and interfaces to these tools has created methods and techniques for testing and usability studies (see section 2.3). As indicated above, information seeking should be seen as an interactive process and deals with people that in different ways interact with the IR environment. Since the IR interaction also includes the problem of design (see 2.1), it has drawn attention to research from within both the information science and computer science areas (e.g. Koenemann and Belkin, 1996; Brajnik, Mizarro and Tasso, 1996). It has been shown that there are individual differences when performing information seeking tasks within IR systems. Borgman (1989) reports that individual differences were found when investigating technical aptitudes and personality characteristics in relation to academic orientation (Borgman, 1989, pp. 242-248). Furthermore, Borgman suggests that these individual characteristics have implications for both design and training of users of information systems (ibid, p. 248-249).

2.2.2 Browsing and searching strategies

Browsing and searching strategies are two concepts that need to be further described. A *strategy* can be viewed as the approach an information seeker uses to solve an information seeking task or problem (Marchionini, 1995, p. 72). In the traditional online database environment, the information seeking activity is mainly characterizedas searching, although you can use browsing to investigate and explore subject or thesaurus lists. In the network-based (hypertext/media) information systems environment, due to its nature of hypertext links and nodes, we can talk about the concepts of searching, browsing and also navigation. There is an ongoing discussion of the definition and distinction between browsing and searching. In a doctoral thesis, by Shan-Ju Lin Chang (1995), the browsing concept is discussed, and an enhanced framework for the understanding of the browsing activity is suggested. In her conclusions Chang makes the following distinction between browsing and searching: "The

nature of browsing is fundamentally evaluative and inclusive. Searching (or non-browsing), on the other hand, is indicative and exclusive. Evaluative means comparison and contrast among alternatives and thus supposes the inclusion of many alternatives not known beforehand for further examination. Indicative means seeking a definite target and thus the exclusion of other choices." (Chang, 1995, p. 201). Chang suggests that browsing can serve as a search strategy.

Marchionini (1995) talks about information seeking as the generic term and includes searching and browsing as two extremes on the same scale. He describes searching as an "analytical" strategy that is goal driven, systematic and dependent on planning (identify), while browsing is a strategy that is continuous, informal and "proceed according to cues that arise in the data as the search progresses." (Marchionini, 1995, p. 73). In our study, we adopt Marchionini's definition of search strategies or information seeking strategies as:

> "... defined on a continuum with analytical and browsing extremes. The distinction among search strategies is largely indicated by how parallel and tightly integrated the information-seeking sub-processes are. The most carefully planned analytical search shows the sequential steps through the sub-processes, and the most casual, observational browse illustrates the examination of the environment, which stimulates acceptance, definition, and reflection in parallel" (Marchionini, 1995, p.161).

In our study we will view the concept of browsing and searching as a general term of *how* a user seeks information.

Navigation has different meanings depending on discipline. At a general level, navigation could be understood as a conscious activity and way to seek information (Benyon and Höök, 1997). Some suggested sub-categories within the HCI area are social navigation, "wayfinding" and exploring. In the area of IR interaction, Peter Ingwersen talks about information needs and navigation at two levels. In stable and well-defined information needs to verify text entities with known data on topical level, the user uses *confined navigation* which requires some kind of filtering behaviour. In variable and well-defined information needs to clarify, review or to explore information at a topical level, the user uses *exploratory navigation* which require dynamic interaction (Ingwersen and Willett, 1997). Navigation will not be further examined in this study.

2.3 Information retrieval evaluation

Generally, one of the main tasks of evaluating IR systems is to obtain information about the satisfaction of the user's task in a specific work environment. Traditional IR experiments have been carried out for almost forty years such as the Cranfield and TREC (Harman, 1995) studies. Studies conducted by Robertson and Hancock-Beaulieu (1992) and Su (1992) investigate user behaviour, interaction and IR systems.

Within HCI research, there has been extensive work within the usability[4] evaluation area. To begin with, we need to make a distinction between *formative* and summative evaluations (Löwgren, 1993, p. 52), where the former evaluates the product, tool or service before and during the development of that tool. This way it is possible to conduct several iterative[5] evaluation stages "as it is being developed" (Hix and Hartson, 1993). Formative evaluation generates different types of data such as quantitative numeric data sets and qualitative, nonnumeric data sets such as lists of problems that could be used in order to modify and improve the interface

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[4] Usability is a general concept that is related to the effectiveness and efficiency of the user interface and the system, and to the user's reactions to that interface. Generally, usability are concerned with four major parts of any work situation: user, task, system, and environment. Some of the characteristics that is investigated are ease of learning and subjective user satisfaction. Relevant issues include design procedures, design guidelines, and evaluation methods. Examples of methods to identify user interface problems are heuristic evaluation and Cognitive walkthrough (Nielsen and Mack, 1994, pp. 1-2).

[5] The basic idea is that the evaluation is done in several steps until satisfactory results are reached. Generally this is achived through following a design-cycle containing prototype, evaluation, requirements, design and implementation. This cycle is then repeated several times.

design (Hix and Hartson, 1993, pp. 283-286). In contrast, the summative evaluation, is done after a product, tool or service is ready for marketing and then an evaluation test is performed to measure the usability of that tool. Our study is influenced by this formative evaluation method approach. Usually, these evaluations and user tests are conducted within a highly controlled laboratory environment, where subjects are performing specific tasks and are observed using different techniques like "Talk aloud" or video-recording, etc. Some evaluation methods used within HCI are heuristic evaluations[6] (Nielsen and Mack, 1994) and cognitive walkthrough[7] (Wharton et. al., 1994) which can be described as expert methods (i.e. a set of experts on interface design). Task analysis (TA) is another method (see section 2.5), which builds on the assumption that the user's interaction with a system is based on a set of goal(s). In this analysis, the system is broken down to low-level tasks that will be accomplished by the user. In our study we will use a formative evaluation and use a task analysis method to describe the tasks within the information system.

In our exploratory study we have applied HCI evaluation techniques to our IR evaluation to establish a connection between the traditional IR and the HCI evaluation methods. In order to understand the IR interaction for our evaluation purposes, we present the following evaluation framework:

- the setting for our data collection. This means that we will have to describe the type of IR setting and the database. In our case it is a hypertext/media IR system (chapter 3).
- variables (values) to be studied and examined. In traditional IR settings, the standard measures of IR effectiveness are those of precision and recall. There is a need to analyze additional measures like user satisfaction, user knowledge, previous experience and preferences, browsing/searching strategies (chapter 5).
- a set of data collection methods. This is done using both quantitative and qualitative data collection methods like questionnaires, open-ended answers, transaction logs and task analysis (chapter 4).
- analysis methods by which the variables can be examined (chapter 4).

According to this framework, we will use the data collection and analysis methods described in section 2.4 below. Special considerations are taken to the fact that our IR system evaluation is done within a hypertext/media environment. In this kind of environment, the end-user is the primary user and information seeker, employing different kinds of IR systems and user interfaces (where our Dienst system is one of them), which offer different kinds of support and interactivity. Special problems are the support for both browsing and searching activities, as well as for navigation.

2.4 IR interaction and user interface design

The main function of the system is to support the human user in her task(s). This task could be some activity that involves gaining a particular goal or purpose. The goal could be to acquire some change in the user's state of knowledge. Support should be designed to provide the user with the necessary assistance in gaining her goal.

A user interface to an information retrieval system can be described as a "front-end program which interacts with the user and controls an underlying information retrieval system accessing information resources" (Brajnik, Mizarro, and Tasso, 1996, p. 128), which includes built in possibilities for communication, interaction and different functions and tools to support the user. In information retrieval interaction, the user interface is the primary mechanism and serves as a link or a communication channel (Marchionini, 1992, p. 156) between the user and the computer (system). Information systems are becoming increasingly accessible to end-users and there

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[6] Heuristic evaluation is a technique where a small group of experts (for example three to five) evaluate the design of a system. To do this, a set of usability guidelines are used.

[7] Cognitive walkthrough is f several structured walktrough methods (Löwgren, 1993, p. 53). Cognitive walkthrough is a theory-based method to perform usability evaluations of user interfaces and emphasize basic usability principles. The goal of cognitive walkthrough is to focus on user's cognitive activities such as the goal and knowledge of a user while performing a specific task.

is a growing number of distributed, networked information sources. One problem when dealing with the design of information systems has been formulated by Marchionini:

> "We cannot discover how users can best work with systems until the systems are built, yet we should build systems based on knowledge of users and how they work. This is a user-centereddesign paradox" (Marchionini, 1995, p 75).

Generally, IR systems are designed and implemented in order to support the user in her information seeking activity. In HCI research the main goal is to investigate and improve the interaction between the user and the computer. HCI as a research field includes, on a general level, user interface hardware and software, user and system modeling, cognitive and behavioural studies, human factors, empirical studies, different methods and techniques (some described in Norman, 1986 and Dillon, 1996), and tools. Generally, the user interface can be divided in 2 parts: the development of interaction components and the development of interface software. The difference between them is that the interaction component deals with how a user interface works and its behaviour in response to what the user does while performing a task. The interface software deals mainly with the implementation of the code for the interaction component (Hix and Hartson, 1993, pp. 5-11). For our study purpose, we will focus on the interaction component. There are different interaction styles to choose between when designing the interaction component. Interaction styles are described as a set of interface objects that provide different views on how the user can communicate with the system. Common interaction styles are typed-command languages, menus, windows, boxes, graphical interfaces (Hix and Hartson, 1993, pp. 58-59). Many of these are used in, what is called, direct manipulation interfaces where the user directly performs the actions rather than indirectly (i.e. describing the actions to be performed in writing). Some of its research focus is evaluating and designing user interfaces by using different methods and techniques (Norman, 1986) and usability studies conducted and (described by Dillon, 1996).

As Allen (1996b, p.45) points out, there is a need to establish a link between research within Library and Information Science (LIS) and the design of information systems (including user interfaces), especially concerning the methods for evaluating information retrieval systems, focusing on the *usability* of the user interface and on how well users can accomplish their goals through the system. This will be established in chapter 4.

2.5 Task analysis

Generally, in user interface design process, the focus is on understanding who the users are and what the tasks are. The task of information seeking is complex, and tasks can vary from finding specific information (known item) through query formulation to a more open-endedbrowsing activity involving exploring the database or information space. There are different levels of tasks. One important factor influencing the information seeking process is that the user' task could be thought of as being comprised of the problem that the user has to solve as well as the task that the user has to perform in making use of the system. Secondly, the information seeking activity can pose a problematic situation. All the questions used in the study deal with some problems encountered in this activity (see section 5.3 and 5.4). Thirdly, it is therefore important to understand what a user is required to do when entering the information system. In chapter 5.6 we analyze the IR system and what task the user is required to perform using the system.

In the HCI area, task analysis can be describedas a set of techniques used by e.g. system designers to describe and evaluate the human-machine interactions in systems. Task analysis is usually used in the early stages of the evaluation and design of the system, but it could also be used iteratively throughout the design phases. Generally, task analysis can be defined as the study of what a user is requiredto do, in terms of actions and cognitive processes, to achieve a goal. The goal of task analysis is to acquire a better understanding of how people interact with the system and system components and should lead to a more efficient and effective integration of human knowledge in terms of system design and operations/actions (Diaper, 1989). Hierarchical Task Analysis (HTA), is a method that is based on a graphical representation of tasks and subtasks of an overall goal within a certain environment. HTA can be described as

> "a general form of task analysis, capable of dealing with cognitive as well as motor tasks, that embodies principles that are just as relevant to HCI tasks, especially with regards to aspects of training and supporting skills" (Shephard, 1989, p. 16).

In this method, the aim is to describe the way(s) in which a goal may be achieved. HTA deals with the general and logical steps necessary to achieve the stated goal and these are then verified with real users during the evaluation and analysis of the system.

To understand users of information systems, we need to know what tasks they have to accomplish. We will use the task analysis method to describe the different tasks, which are offered to the user within the Dienst system and then construct graphical representations of these tasks. This will be done in section 5.6.

3. The Domain

For our study purpose, we will use the Dienst database system, version 4.0. The Dienst system (Davis and Lagoze, 1994) was originally developed at Cornell University and Xerox Corporation in 1993 and further developed at Cornell University for the ARPA-funded Computer Science Technical Reports project in the USA, and now forms the basis of the Networked Computer Science Technical Report Library (NCSTRL) (Lagoze and Davis, 1995). The first attempts to establish a comprehensive report archive or library were done in 1993, when the system called Unified Computer Science Technical Reports Index (UCSTRI) was set up. Improvements to the UCSTRI system came with the systems of WATERS (Wide Area Technical Report Server) and Dienst. In 1995 both WATERS and Dienst was combined into the Networked Computer Science Technical Report Library (NCSTRL) initiative.

3.1 Dienst system and protocol

The Dienst system is a protocol and implementation that provides access to distributed, decentralized, multi-format document collections over the World-Wide Web. Interoperability among Dienst servers provides the user with one single logical document collection distributed over the Internet and centralized searching of a physically distributed collection.

The Dienst architecture has the following components: the repositories of multi-format documents; indexes and a search engines for these indexes; and user interface for browsing, searching, and accessing the archives and a library management service. The Dienst architecture could be described as both a local server for one individual site, and a network of servers. This technology is not specifically designed for the computer science technical reports domain, and can be used within other domains as well. A domain can be described as a body of knowledge, consisting of entities and relationships within this body. Dienst servers are accessed through gateways from any WWW server that supports CGI[8]. The Dienst protocol requests uses HTTP, the WWW protocol as a transport layer, making Dienst servers accessible from any WWW client (browser).

The Dienst server has four components: a document database, the server, the WWW server, and the Dienst CGI (Common Gateway Interface) programs. The Dienst system provides features such as: uniform ways to search and access the elements in the collection without regard to their physical location; multiple representations of a document (e.g. Postscript[9], GIF[10], HTML[11] etc.); documents as structured objects, which could be physical such as pages, or logical such as chapters, tables which can be viewed as a whole or in parts. Each document also

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[8] Common Gateway Interface (CGI) defines how a server and gateway programs communicate by specifying a set of environment variables. These variables provide the gateway program with information such as address of the remote client etc.

[9] Postscript files are text files or documents, with the extension .ps.

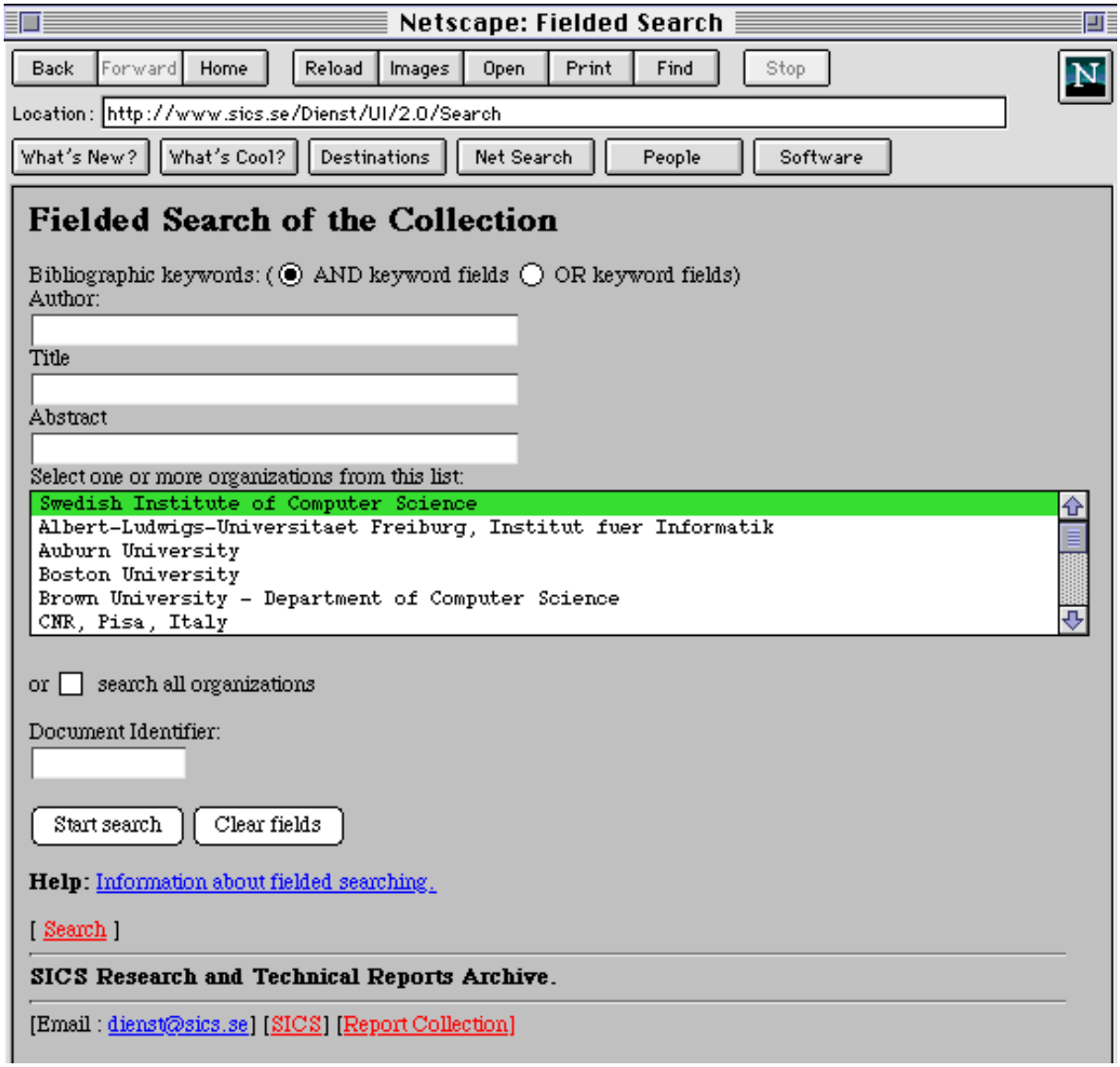
[10] Graphical Interchange Format. Pictures are stored as binary files. One format of such a de facto standard is GIF

[11] HyperText Markup Language (HTML) is a document markup language within the WWW. HTML is a simple markup language used to create hypertext documents that are portable from one platform to another.

has a unique location-independent identifier or document name. One special feature with Dienst is that indexes are distributed and searches are processed in parallel across each index site. The Dienst system handles search requests by embedding them in HTTP transactions (the WWW protocol), and currently, Dienst provides two types of search options: bibliographic and full-text search and the IR technique used is the well known Boolean logic. The user can search the collection by author, title, number, abstract keywords, etc. Finally, Dienst provides a set of tools to administrate the local collection. These tools can be used to index the collection, format conversion and so on.

From a user view, the report collection consists of a unified archive of uniquely identified reports, each of which may be available in several formats. Using public available WWW-browsers, Dienst user interface allows the user to search, browse and view the collection. Some features within the Dienst are: form-based fielded searching (Figure 3); unified hypertext hit list; abstract page; structural overview; page browsing via thumbnail images; inline page image; page level zooming; click-to-search full-text search; printing and downloading

Figure 3. Advanced query page in Dienst

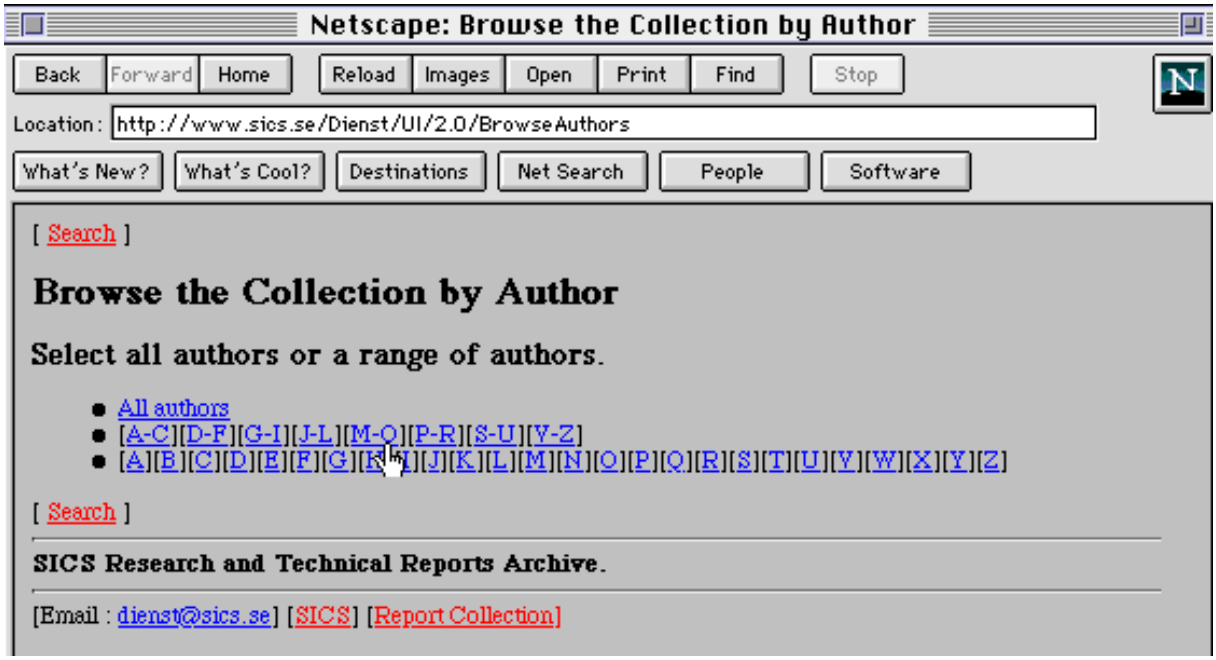


Among Dienst search functions we can mention the form-based fielded search which are covering publisher, report-number, author, title, abstract and follows rules for bibliographic keyword matching as follows:

- All matches are case insensitive.
- Boolean operators. The value for a keyword field may contain the logical AND and OR. Parentheses may be used to group words (comp OR (Perl AND scripts)).
- The search string may specify either the logical operator AND or OR between the bibliographic keyword fields, or specify the AND or OR in the term list.

Furthermore, the user can e.g. browse an alphabetical list of authors (Figure 4); numerical list of years of publication; or institutions connected to the distributed collection.

Figure 4. Browse Author page in Dienst



3.1.1 SICS database for technical and research reports

This study is based on a previous project, initiated by the European Research Consortium for Informatics and Mathematics (ERCIM)[12], in which SICS participated. Within the ERCIM project, a set of distributed servers were installed, including one at SICS in 1995[13]. This was part of an European and global distributed collection of reports within the computer science domain. The database was installed under a SICS local HTTP server[14] and the reports were indexed, stored and accessible through the WWW user interface. The study is based on a basic version which means that we have made available most of the features except for thumbnail images; inline page image; and page level zooming (section 3.1).

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[12] ERCIM is an organisation dedicated to the advancement for European research and development in the areas of information technology and applied mathematics. The national member institutions aim to foster collaborative work within the European research community and to increase cooperation with European industry.

[13] The SICS database is available at the following URL: http://www.sics.se/dienst/dienst.html

[14] HyperText Transport Protocol (HTTP). The protocol of the WWW, which allows WWW-browsers and WWW-servers to communicate with each other..

4. Research Design and Methodology

As indicated, the purpose of this experiment is to investigate the information seeking behaviour and interaction with a WWW-based IR system. The methods used in this thesis combines both the IR interaction perspective and the user-centered design methods in HCI. The method has the following goal:

- to combine both the IR interaction perspective and the user-centered design methods in HCI
- to implement the study in an experimental real-world online WWW setting
- to collect cognitive and statistical data from users performing an information seeking task using a combination of both qualitative (questionnaires) and quantitative (transaction logs) data collection methods
- to analyze collected data according to how users interact with the information system in order to make suggestions for supporting user characteristics and needs in the user interface redesign

4.1 The experimental study set-up

To perform this study, we used the Dienst server at SICS, described in section 3.1. The data were collected during August-November 1996. To accomplish our task of investigating the user activities and linking them to the user interface design, we will follow a model and a framework (Table 2) proposed by Allen (1996a, p. 24) which is slightly modified[15]:

Table 2. Model for user-centered IR interaction and interface design (based on a model by Allen, 1996a, p.24)

COMPONENT	*METHOD*	*TASK*
Resource Analysis (chapter 3)	Description of information system functionality	Describe resource(s) that are used to complete the tasks.
User Needs Analysis (section 5.1 to 5.4)	1. Questionnaire with 5-point scale ratings and open-ended questions (qualitative and quantitative data) 2. Log statistics (quantitative data)	1. Users goals, purpose, objectives, actions, individual preferences. 2. Logging user transactions. Measures like time, no. of actions and type of actions
Task Analysis (section 5.6)	Hierarchical Task Analysis (HTA)	Users' tasks, goals and activities that they accomplish when meeting their needs.
(User Modeling)		Merging needs, user tasks and goals, and system tasks
Designing for Usability (section 5.5)	Requirement lists (qualitative data)	Requirement elicitation for redesign of the user interface

This model also requires the understanding of system and user interface usability as a basis for user interface design and as an evaluative criterion. Allen's model contains a set of components important for an IR system evaluation. To accomplish these analyses, we use different methods that will describe the system, the user's activities, user's tasks, and finally to acquire requirements for the design of the user interface.

We also need to know about the user's behaviour and strategies, goals and tasks, preferences and differences. This will be done through online questionnaires and transaction log statistics. We need to know about the tasks the users have to accomplish in this study. A formal description of the information system, using the task analysis method will be done. Finally, we need to draw conclusions from the analysis, and based on these results suggest important factors for the user interface (re)design. This will be described in chapter 6. Ideally, we suggest that the refinement of the user interface will be an iterative process, since changes must constantly be checked against users and the environment.

For the evaluation task, we used a combination of data analyzing methods, which was implemented in an experimental real-world online WWW setting. This evaluation methodology combined online (WWW-based)

[15] We have excluded the "User Modeling" component for our study purpose. Although some of the results from our study could be part of a user model, this study is too limited and a user model will be suggested for future studies.

questionnaires and database transaction log statistics. To accomplish our task, we decided to use a combination of both qualitative and quantitative data collection methods. Table 3 summarize our methods used, types of data collected and analysis methods:

Table 3. Types of data collected, data collection methods and analysis methods.

Data collection methods	*Types of data collected*	*Data analysis methods*
Internet-based evaluation questionnaires before and after information seeking task	1. Quantitative data: 5-point Likert scale from questionnaire. 2. Qualitative data: Written (open-ended) data to the 5-point Likert scale	1. Quantitative data analysis 2. Qualitative analysis of written data 3. Comparison of statistical data 4. Task analysis of qualitative data
Download of search log history	Quantitative data: Log statistics	Quantitative data analysis

The following data collection methods have been used:

Questionnaires (or structured interviews) were used to collect and extract users' opinions and satisfaction with the use of the system. This data were collected at two occasions, before and after using the system. The pre-search questionnaire contained 2 parts: part one collected demographic data (app. B) and part two contained five questions explored the user's preferences, intentions and goals. The post-search questionnaire, which contained nine questions, explored factors such as satisfaction with the search result, and satisfaction with navigation support to complete an information seeking task. Answers to the questions were made on a 5-point Likert[16] scale, to be checked by the user. Furthermore, after each question, an open-endedquestion (Losee and Worley, 1993, pp. 133-134) field was offered. The questionnaires were set up in a non-controlled situation, i.e. the subjects were asked to participate and the questionnaires were made available online so that the subjects could do their search through the system at any time. We contacted potential participants in one of three ways: personal contacts, electronic mailing lists or through recommendations. All subjects were approached via email. The selection of subjects was based on the potential interest in the subject domain (computer science). The forms, containing the questionnaires, were written in HTML and integrated into the database interface and executed via the Common Gateway Interface (CGI) technology. The answers were then sent (through a program) to the mailbox which was set up for this study, and a copy was sent to the subject as well. The questionnaires were first tested on a small group of subjects (Losee and Worley, 1993, p.134) and some changes to the question formulation were made.

Written or "open-ended" data : In addition to every question within the questionnaires, there was a "comment"-field, where the subject could submit information to clarify or verify her statement on the 5-point Likert scale. We adopted this method because we thought that this would give us valuable information in addition to the statistical data. This way the data collected could be measured both quantitatively and qualitatively.

Database transaction log: To automatically monitor the users' interaction behaviour, we made use of the Dienst system log. Logging user interactions did not influence the user's information seeking task. Data were collected from the database transaction log capturing each online user's server requests. The data was stored in a separate file. This record contained information about the subject's machine-address, the amount of time, the total of actions and types of actions made.

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[16] Likert scales are characterized by a set numbers of choices, usually 5, 7 or 9. A method designed to scale subjects and which is used to gather individual differences in attitudes concerning an issue. The subject examines an item and respond accordingly to a scale generally from 1 to 5 or 7 (Ghiselli, Cambell and Zedeck 1981, p. 413). Generally, the Likert scale offer five response categories ranging from negative to positive responses, with a category of "undecided" as the middle score or as a separate score (Babbie, 1983, pp. 380-381). In our study we use the "undecided" score as the middle (point 3) score.

4.2 WWW-based evaluation

Information retrieval systems, techniques and tools have been evaluated for a long time. The evaluation has mainly focused on effectiveness measured through precision and recall. Through the emergence and development of computer networks, users can easily access the information and the database systems themselves. In this study, we will provide and combine a set of methods that will help us in gathering and analysing the data from actual users with actual information needs. Our study proposes experimental and exploratory means of evaluating an information system online. The study of the Dienst system began with actual users involved in the evaluation phase of the current user interface. This was done by putting the evaluation part of the design cycle on the WWW. We then analyzed the data which generated requirements for a redesign. This is one way of extending the use of existing methods of evaluation of user interaction and user interface. Iteration between evaluation, requirements review and redesign could continuously be executed, until a satisfactory level of design has been reached. We should however remember that this is the first experimental attempt in this particular environment, in moving parts of the usability lab onto the WWW. As we make information retrieval tools, like Dienst, available on the WWW, they can provide us with a good opportunity to get feedback concerning functionality, design and user behaviour (Höök, 1996a).

Using questionnaires and combining both quantitative and qualitative data collection methods created a large set of data that could be analyzed in many different ways. The Likert rating scale provides a set of ordinal values which was used to give an indication of both the nature and magnitude of the subjects' (subjective) opinions. We decided to use questionnaires because it was easy to administrate the data sets and that there was no time limit to complete the questionnaire. It was also easy to distribute the questionnaires over the World-Wide Web. Using email, we could easily announce the questionnaires world-wide or to a small selected group. Using email and WWW as tools for this evaluation there was no interference from other users conducting the task at the same time, and above all, the study could be performed in a real situation and created real empirical data to be evaluated.

As previously stated, the methods used in this study created a large amount of data that had to be evaluated, coded and structured and this data gave a good opportunity and framework for extracting results. Qualitative (open-ended questions) and quantitative (Likert scale ratings) data, have to be treated differently. The planning of the analysis is important. Data collection and analysis is a selective process, especially when dealing with qualitative data. First, the "raw" answers need to be transcribed into a general level of semantics that can be understood and some kind of matrix or categories to match the data against need to be established. This is problematic, since words may have different meanings and interpretations, and numbers (quantitative data) can be processed more generally and economically. The use of questionnaires created two kinds of problematic issues within this study: firstly, formulating appropriate questions that generated "right" answers on the Likert scale, and secondly, that the open-ended questions that should provide meaningful data set. This created a problem, especially in that these questions were of open-ended type dependent on the Likert scale rating.

Problems: One experience encountered, was that the number of questions was too high (5+9), that is, the answering rate on the open-ended questions decreased in the second questionnaire. These problematic situations resulted in that we had to withdraw some questions due to both wrong formulation, and also that some open-ended questions had a low answer rate in our study. Another problems was that we could not use the transaction log statistics to verify all the answers in the open-ended questions in the questionnaire. To verify more complex written answers, the log file need to be more "intelligently" enhanced. On the other hand, using log statistics, no human evaluator was needed during the data collection period. Furthermore, in this way we did not influence the user's activities. About 150 subjects were approached mainly by way of e-mail. 38 subjects replied. 9 other subjects answered the first question, but not the second and were consequently excluded. This means that, when doing a non-controlled WWW-based evaluation, there can be a large loss of subjects and therefore also a loss in systematically collecting all subjects during a certain time period. The whole process of managing and administrating our study in a non-controlled situation was easily performed within the WWW environment. The big efforts though, lies in analyzing the collected data.

4.3 Data collection and analysis methods and procedures

The combination of data analyzing methods (see table 3) was implemented in an experimental real world WWW setting. The objective of our *analysis task* and method was to gather information about the user's knowledge, information seeking behaviour and strategies, that then could be used for a redesign of our user interface, in order to better support the users. We combined both quantitative (statistical analyses of database transaction logs and Likert scale ratings) and qualitative (content analysis of written data) approaches. Findings of the data analysis will be presented in chapter 5 and discussed in chapter 5.7.

Questionnaires: The questions represent a set of variables to be measured. For the selected single variables we used statistical analysis (Likert scale ratings from one (1) to five (5)) to establish tendencies through measures of the mean value. To measure the relations between two single variables, we used the Pearson correlation (r)[17]. In general, when analyzing the statistical data, the scores on the Likert scale were grouped as follows: point 1 and 2 ("low score"), and 4 and 5 ("high score") were grouped together. Scores in the middle (point 3), were treated separately. When measuring the relation between two variables we present the data in tabular format (see Table 13).

Written or open-ended data: Content analysis was used on the data from the comment-field following the questions in the questionnaire to identify and clarify the measured single variables. These written statements were also used to build lists of requirements of user needs regarding functions/services or design issues. Transcripts from the written data were coded to describe a certain meaning or statement to establish a structure and organization of that data.

Transaction log data: Transaction logs were used to observe the subjects real actions and collect information about individual information seeking sessions and to measure time. This data were matched to the data submitted by the users in the questionnaires for validity checking and discrepancy. The quantitative data in the questionnaires and from the log statistics generated objective data that was analyzed. Finally, the different types of data collected were examined at three levels: a) the *general* level (all users); b) the *group* level (all users in that group); and c) the *individual* level (single verbal statement).

In summary, the data collection and analysis were conducted as follows: First, we approached potential participants, and secondly, when the participant had conducted the task, her answers from the questionnaires and the log statistics were linked together, creating an individual record of the subject. Finally, we created a coding scheme, a set of categories, and iteratively ran our data through that scheme.

4.4 The subjects

The system was not previously presented for the subjects, and thus the subjects entered this particular system for the first time. The study was conducted in a real environment and with real users and information seeking situations. The subjects were asked to perform an information seeking task based on a real information need. 38 subjects (16 female, 21 male, and 1 anonymous) completed the questionnaires. The selection of subjects was based on their potential interest in the computer science subject domain. To group the users, we assumed that only subjects with interest in this very specific subject domain, would be included for our purposes at this stage in our study. This resulted in a first user categorization of users with related activities, i.e. computer scientists, librarians, information specialists, consultants, developers and designers within the computer science area. In the second categorization we grouped the users as follows: Computer Science researchers (CS), Industry (Industry) and Information Specialists and Librarians (ISL). 37% of the participants were computer science researchers, 24% worked within industry, and 39% were information specialists and/or librarians. To perform the study, the subjects received an URL[18] to access the database.

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[17] Pearson correlation measures the strength of association between 2 variables (Losee and Worley, 1993)

[18] Uniform Resource Locator is a standard way to specify the location of a resource available electronically on the Internet.

5. Results

The method and research questions described in section 1.1 and chapter 4 were evaluated in a study during August-November 1996. The data collected were measured at three levels: a *general* level including all users; a *group* level including all users in that group; and finally at an *individual* level.

In our study, we have focused on the following categories: user background, knowledge and preferences (chapter 5.2); user satisfaction (chapter 5.3); information seeking strategies such as browsing and searching (chapter 5.4); and user requirements elicitation (chapter 5.5). First, we examine the single variables in the two questionnaires. Secondly, we compare the variables and study the relations between different variables. Thirdly, through analysis of written comments, we extract data to establish tables of requirements, which will, together with the findings from single and combined variables, provide a framework from which we will make suggestions for a redesign. The categories were measured through a set of variables described for each category.

5.1 Analysis of quantitative and qualitative data

Before we look at our findings, we first present some general statistics from the study. We have a satisfactory rate of 95% for the 5-point Likert scale (503 out of 532 questions) in the *questionnaires* (Table 4).

Table 4. Answering rate of the Likert scale part of the questionnaires

	ALL	*CS*	*Industry*	*ISL*	*MEAN*
Total	503 N=532	180 N=196	122 N=126	201 N=211	13,23 N=14
Answering rate %	95%	92%	97%	95%	95%

Concerning the *transaction log statistics*, the mean time to complete an information seeking episode or session was 11,5 minutes (Table 5), and the mean number of actions made within a session was 9,6 actions, which gives us 1,1 minutes per action. 19 (50%) of the 38 subjects used both the browsing and the searching actions. 17 subjects used only the search functions, and 2 subjects only the browsing functions. For a categorization of the actions into search or browse actions, see chapter 5.4. Analysis of the user log indicates that subjects used both browse and search actions to accomplish a task. Furthermore, high degree of the subject used only search actions, and considering that many subjects indicated that they wanted to browse, we must conclude that there was poor support for browsing in the system.

Table 5. Mean score of transaction log time and numbers of action.

	TIME		*ACTIONS*		
GROUP	*Total*	*Mean*	*Total*	*Mean*	*Mean time/action*
CS	164	11.7	147	10,5	1.1
Industry	85	9.4	79	8.7	0.92
Information specialists/Librarians	189	12.6	140	9.3	1.3
N=38	438	11.5	366	9.6	1.1

Concerning the *open-ended questions*, A total of 302 statements were given (Table 5). The answering rate was 57% with 8 statements per subject in average. Both the CS and the ISL group had about a 60% answering rate, while the Industry group had a rate of 40% on the average. When presenting our results, we have excluded questions Q12, Q13 and Q28, since they were not of interest for this study. Appendices C and D contain the complete set of data from the questionnaires. It should be noted that the results and the following conclusions mainly concerns computer science domain, but the implications drawn in section 6.1 could represent important factors to be considered for IR (user interface) design in general.

5.2 User background, knowledge and preferences

First, we investigated users different *preferences* i.e. background, knowledge, and goals. In the first part of questionnaire 1 and open-ended questions in questionnaires 1 and 2, we measured the following variables: background and gender, user groups, previous experience with hypertext systems, IR knowledge, user's expectations before and after using the system, and user's tasks and goals.

User groups

As the subjects were involved with or potentially interested in the computer science domain, and therefore also the content of the database, we were able to categorize the subjects into the following general user groups: Academic computer science researchers (CS), industry (I) and information specialists and librarians (ISL). Using the background questions in questionnaire 1 (appendice B), we collected information about the subject's occupation and education (Table 6) and created a simple set of three user groups, their education area, and gender.

Table 6. User groups and gender

User Groups (Occupation)	*Education*	*Gender*			*Total*	*%*
		Female	*Male*	*Anonymous*		
Academic Computer Science researchers (researchers and students) (CS)	Computer Science Natural Science Engineering Social Science	6	7	1	14	37
Industry (consultants, engineers, publishers and researchers) (I)	Computer Science Social Science Management Library Science	1	8	-	9	24
Information Specialist and Librarian (ISL)	Social Science Library Science Natural Science Computer Science Engineering	9	6	-	15	39
TOTAL		16	21	1	38	

Professionalbackgroundandgender

Table 6 shows the subjects' professional backgrounds and gender. 37% of the participants were computer science researchers, 24% worked within the industry, and 39% were librarians and information specialists. 42% of the subjects were female, 55% male. One (1) participant were reported as anonymous.

What we can see is that the subjects are diverse and heterogeneous in respect to occupation and education, especially within the ISL group. This could be explained by the fact that many within this group had other previous training and occupation before working as librarians or information specialists.

Statistical analysis of selected single variables from the first questionnaire (Table 7), shows rates given for both the all subjects level and on the group level. In the first section, to the left, we have the questions provided for the subjects with the Likert scale ratings, extremes ranging from 1 to 5, followed by the three user groups. The third section contains the scores for the user groups respectively within the Likert scale 1 to 5. The next section to the right contains the mean value for all subjects, and also the mean value for the three user groups respectively. The last section displays the number of subjects that contributed to the questions asked.

Table 7. Statistics of selected variables in the first questionnaire

Question	*Group*	*1*	*2*	*3*	*4*	*5*	*Mean*	*Subjects*
Q11	***All subjects***	***13***	***6***	***7***	***7***	***5***	***2.60***	***38***
I have a clear knowledge about what I am looking (searching) for.	CS	6	3	2	3	0	2.14	14
1 = No, I am just browsing	Industry	2	1	3	3	0	2.78	9
5 = Yes, I know exactly.	Inf. Spec/Librarian	5	2	2	1	5	2.93	15
Q14	***All subjects***	***1***	***5***	***5***	***7***	***20***	***4.05***	***38***
I am used to searching for information in hypermedia systems.	CS	0	3	1	3	7	4.00	14
1 = No, not at all.	Industry	1	1	0	1	6	4.11	9
5 = Yes, I often look for information this way.	Inf. Spec/Librarian	0	1	4	3	7	4.06	15
Q15	***All subjects***	***3***	***1***	***7***	***9***	***18***	***4.00***	***38***
I know how to formulate queries	CS	3	0	4	4	3	3.28	14
1 = No, I just try with what I know	Industry	0	1	1	2	5	4.22	9
5 = Yes, I know how to formulate queries.	Inf. Spec/Librarian	0	0	2	3	10	4.53	15

As we can see, the method of interaction or the *browsing/searching strategy* (Q11) has a mean score of 2.60, and there is a tendency towards preferring browsing by the subjects in their information seeking task. Even when the subjects did know that this was an IR system and that such systems usually include search functions, they expressed a need to browse through the system. At the group level, we found that the CS group had the strongest tendency to browse (64%). The ISL group, that had a subset of subjects, was the only group that had a clear knowledge of what to search for (33%). One explanation may be that the ISL group has professional experience and is trained to search in online databases. They know how to pose queries and to structure their information seeking tasks. Based on this result, we can make a distinction between one group that has IR knowledge and another with no or little knowledge.

The variable *previous experience* (Q14) of information seeking in hypertext systems has a high mean score of 4.05. 71% of the users had a high level of previous experience. 16 % had no or very little experience with hypertext systems. Each user group had at least 67% high level of previous experience. The result indicate no further need for explanations of how to use hypertext systems. This is also confirmed by the result of Q25 (understanding of terminology, chapter 5.3).

We also found a strong tendency for a high *IR knowledge* (Q15) when it comes to formulating queries, with a mean score of 4.00 among the subjects. At the group level, ISL had a high mean of 4,53. Low IR knowledge was found in the CS group (21%). The high score for the ISL can be explained by that subjects within these groups are trained and skilled searchers. It also gives us evidence for the categorization we made between the CS and ISL groups. Generally, the subjects have a basic knowledge of how to pose queries, except from a small group within the CS. This could be further explained by the fact that end-users more frequently than previously are exposed to information seeking in electronic environments (e.g. AltaVista). This also tells us that the ISL group could be categorized as IR experts. This confirms that there are differences between the groups.

User expectations - before and after using the system

To gain further information about our subjects, we also examined the subject's expectations both before and after using the IR system. To accomplish this, we studied the data from two open-ended written questions (Q12 and Q21) on an individual level. The statements were then transcribed and summarized in Table 8. We compared the requirements with the Dienst system (chapter 5.6) to see if the requirements were present or not in the system.

Table 8. Comparison of user expectations before and after using the system**.**

Expectations before		*Expectations after*	
In system	*Not in system*	*In system*	*Not in system*
Research reports (17)	Other information objects than reports (3)	Bibliographic references and List of SICS reports (3)	More reports (5)
Bibliographic references and List of SICS Reports (5)	An order form	Downloading of full-text reports	Subject and keyword list (3)
Fielded search (3)	Keyword List		Reports from other sites (3)
Full-text documents(2)	Proximity search		Query syntax description (3)
Reports from other sites			Database collection description (2)
			Other information objects than reports (2)
			GuidedTour

From the results we can draw the following conclusions: there were functions in the system that the subject did not recognize or could not identify. There were also functions identified that were needed by the subjects. We found, as well, that some of the prior expectations were satisfied after using the system, and that requirements not in the system had increased after using the system. The statements reflected the subject's prior knowledge of what they thought would be needed in a IR system. If we compare the expectations made before and after using the system, we see that there are expected functions that are in the system while others are not present in the system. If we look at those not in the system, we see that all the stated expectations made before using the system are satisfied, but after using the system there are still other functions needed. If we look at those functions expected that are present in the system, all except one are still required after using the system. We also observed that:

- Users have expectations before entering an IR system. These expectations range from type of information to IR techniques. Expectations made before using the system are mostly missing in the expectations stated after using the system. During the information seeking session the users experienced what was present or not in the system, and accordingly set new expectations or requirements. But most importantly, our study shows that the subjects expected functions and/or objects that were *not* present in the system.
- Users are involved in learning the system. The results of the user expectations stated before using the system and expectations after using the system, point out that the learning process also includes new knowledge and requirements as a response to their interaction with the system.
- Another very important finding was that subjects have problems recognizing functions in the system. We found that some of the functions and/or objects asked for before using the system and present in the system, also were asked for after using the system. This indicates that the subjects had problems finding and identifying these functions and/or objects in the current user interface design.

To conclude, we believe that users' expectations are based on previous experience and knowledge in online database information seeking. We also believe that users are involved in a learning process, which is based on previous knowledge and experience during the information seeking process.

User tasks and goals

Finally, users' goals and tasks will affect the information seeking performance and their satisfaction with the system. It is thus important to establish what the goals and tasks are. These can tell us something about what the users are trying to accomplish and give us an understanding on how users perceive that they can reach their goals. We found the users' goals and tasks through analyzing the written comments in the open-ended questions Q13 and Q14. Table 9 summarizes a set of general user goals at the group level, while the tasks used to reach the goals are summarized in Table 10. Generally, goals could be understood as "what is the goal with my information seeking task?" and tasks as "how do I accomplish my goal when seeking information?"

Table 9. Map of general user goals.

GOALS	*Frequency*	*CS*	*Industry*	*ISL*
1. To use in a work task : project or seminar presentation	8	x	x	x
2. To write a paper/thesis/report	8	x		x
3. To learn the database (topics)	6	x	x	x
4. To create an author profile	3	x		
5. To acquire competitive knowledge (developments and IT news)	3	x	x	x
6. To check references	2	x		
7. To gather company or product information	2		x	x
8. To make recommendations for customers	2			x
9. To learn the database domain	2			x
10. To establish contacts with other researchers (addresses)	1	x		
11. To develop IT related strategies	1			x

Tables 9-10 show that users have different tasks and goals on both a general and a group level. In table 9 we have extracted 10 different goals with an information seeking task. One interesting observation is that we can distinguish different contexts, in which the user's tasks have evolved. When looking at the goals stated and transcribed, we can make a simple categorization as follows: an individual (or internal) context level (e.g. 2), a group context level (e.g. 1), and a community level (e.g. 8 and 11). We can also see that some of the goals are overlapping more than one context levels, e.g. number 2 (writing a paper/report), which the user want to do for his own career, but also within a specific group and community. This means that when performing an information seeking task, the user is influenced by the contexts in which the information need evolves. This observation were made during the explorative examination of the data, and since this only have indirect relevance for our study, we will not elaborate on this subject further. This will be an issue for future studies. The three most stated goals were: to use the information in a work task, such as a project or seminar presentation; to write a paper/thesis/report; and to learn about the database topics.

Table 10. Summary of general user stated tasks.

TASKS	*CS*	*Industry*	*ISL*
1. Scanning and collecting through recognition information relevant for my work.	X	X	X
2. Searching for information and meta-information through selecting and specifying a specific topic relevant for my work, i.e. writing a report or background information for a project.	X		X
3. Scanning information for learning and for acquiring "competitive knowledge" within the computer science domain and IT development area.		X	X
4. Evaluating the information resource (the database) for relevance to customers.			X

Table 10 shows the most common tasks stated in order to accomplish various goals. One explanation may be that users, in this particular situation, performed task-dependent activities rather than those based on profiles and characteristics of user groups.

5.3 User satisfaction

Data collected in questionnaire 2 are summarized in table 11, and contained Likert scale ratings, open-ended questions and log statistics. In this questionnaire we excluded question Q28 as not appropriate for our study. Analysis of the second questionnaire focused on the following variables: user satisfaction with the search result, search functions within the system, information content, navigation support to complete an information seeking task, domain knowledge (terminology understanding), system overview, information display, and system effectiveness.

Table 11. Statistics of selected variables in the second questionnaire

Question	*Group*	*1*	*2*	*3*	*4*	*5*	*Mean*	*Subjects*
Q21	***All subjects***	***4***	***7***	***8***	***12***	***6***	***3.24***	***37***
I am satisfied with the search results	CS	1	2	5	3	2	3.23	13
1 = No, not at all.	Industry	2	0	1	5	1	3.33	9
5 = Yes, very satisfied.	Inf. spec/Librarian	1	5	2	4	3	3.20	15
Q22	***All subjects***	***2***	***5***	***9***	***16***	***3***	***3.47***	***34***
I am pleased with the search functions the system offered me.	CS	0	2	3	7	0	3.41	12
1 = No, not at all.	Industry	1	2	4	1	1	3.25	8
5 = Yes, very satisfied.	Inf. Spec/Librarian	1	1	2	8	2	3.64	14
Q23	***All subjects***	***7***	***5***	***5***	***11***	***6***	***3.11***	***34***
The retrieved documents and information were useful to me.	CS	2	4	0	5	1	2.92	12
1 = No, they did not match the information needed.	Industry	2	0	5	1	0	2.62	8
5 = Yes, I'm very satisfied.	Inf. Spec/Librarian	3	1	0	5	5	3.57	14
Q24	***All subjects***	***3***	***4***	***10***	***12***	***7***	***3.44***	***36***
There was enough support for navigation to complete my search.	CS	0	2	6	3	1	3.25	12
1 = No, it did not give any support.	Industry	2	0	1	4	2	3.44	9
5 = Yes, it gave me all the support I needed.	Inf. Spec/Librarian	1	2	3	5	4	3.60	15
Q25	***All subjects***	***1***	***1***	***3***	***8***	***24***	***4.43***	***37***
I understood the terminology used in the system.	CS	0	1	1	2	9	4.36	13
1 = No, not at all.	Industry	0	0	1	0	8	4.77	9
5 = Yes, I understood it all	Inf. Spec/Librarian	1	0	1	6	7	4,.20	15
Q26	***All subjects***	***3***	***3***	***7***	***10***	***13***	***3.75***	***36***
I obtained a good overview on how the information system worked.	CS	0	2	4	4	3	3.62	13
1 = No, it was unclear	Industry	0	0	1	2	5	4.50	8
5 = Yes, I could identify information and function.	Inf. Spec/Librarian	3	1	2	4	5	3.47	15
Q27	***All subjects***	***1***	***3***	***5***	***14***	***10***	***3.87***	***33***
The display of the information was easy to understand.	CS	1	1	2	6	2	3.58	12
1 = No it was confusing	Industry	0	1	1	3	3	4.00	8
5 = Yes, the structure/organization was easy to understand.	Inf. Spec/Librarian	0	1	2	5	5	4.07	13
Q29	***All subjects***	***6***	***2***	***6***	***15***	***7***	***3.42***	***36***
I found my information in an effective way.	CS	3	1	1	5	3	3.31	13
1 = No, it was not effective.	Industry	1	0	1	7	0	3.56	9
5 = Yes, I am satisfied with my search.	Inf. Spec/Librarian	2	1	4	3	4	3.43	14

Findings: On a general level (all subjects) we found a high amount of subjects that scored for point 3 on the Likert scale in the variable *satisfaction with search result* (Q21). If we look at this on a group level, we find that the CS group had the most difficulties in deciding whether they were satisfied with the searches or not. The group rating could also mean that we had a group of novices with no or little knowledge or ability of judging the search results. Finally, we found that the ISL group had a high level of dissatisfied subjects (40%). Analysis of written comments points to the following aspects that should be supported in the system and interface: subject or keyword list; guided tour; and better query syntax instructions.

We also asked the subjects about their *satisfaction with search functions* (Q22). The mean value was 3.47. On the group level, we found that the ISL group was most satisfied (71%) with the search functions, and that they could be considered as experts. The ISL group is skilled and trained for this kind of task. We could also see that the Industry group had a high level (50%) of "undecided" scores (point 3 on a Likert scale). Reasons for this could be an unclear presentation of search functions or low knowledge of making judgments. This group could be characterized as novices.

User satisfaction with information usefulness (Q23) gave a mean score of 3.11. 35% of the users were not satisfied with the information usefulness. The highest level of satisfaction was found in the ISL group (mean 3,57), and the lowest level of satisfaction in the Industry group (mean 2.62). The Industry group also had a high score (63%) of point 3 on a Likert scale ("undecided"). This reflected that they had problems of deciding the value or relevance of the information. Surprisingly, the CS group did not show any significant result concerning usefulness.

The next question (Q24) asked was if the subjects were *satisfied with the navigation support to complete an information seeking task* (mean 3.44). 53% did say that there was good support for navigation, and 17% that there was no or little support for navigation in the system. At the group level, the ISL had a score for high satisfaction with the navigation support in the system (mean 3.60). The CS group had difficulties in deciding whether there was good or bad support (50%). One reason for this could be that, since this group had a high degree of browsing as a interaction method (Q11) and that the system is designed to support searching strategies, this group also had more problems finding support for navigation to complete the task. This will also explain why the ISL group was satisfied with the navigation support, since they recognized all the actions as support for searching, which they all are familiar with.

Furthermore, not directly related to our research questions, we also examined if the mean time and mean action was related to high or low level of satisfaction with navigation support for completing an information seeking task (Table 12), using the database log.

Table 12. Satisfaction with navigation support and mean of time and actions.

Variable	*Mean Time/subject*	*Mean Action/subject*	*Mean Time/Action/subject*
Low satisfaction with navigation support	8.45 min.	10.4	50 sec/action
High satisfaction with navigation support	16.00 min.	11.9	1.21 min./action

The analysis resulted in that subjects who were satisfied with the navigation support, on average spent more time in the system (16.00-8.45 min.), than those with low satisfaction, while the mean numbers of actions did not affect the degree of satisfaction. This shows that the level of satisfaction is time related rather than action-related. The users did mark almost the same number of actions in average, but the time spent was almost (2/1) for these with high satisfaction.

The *domain knowledge or understandingof terminology* (Q25) with a mean 4.43, showed a significant high level of terminology understanding. All groups showed a high level (at least 85%) of good understanding. This confirms that the subjects had a high level of domain knowledge.

There was also a tendency towards a high *satisfaction with the system overview* (mean 3,75) (Q26). At the group level, we noticed that the Industry group had a high level of satisfaction for a good overview of the system (mean 4.50), while the ISL group had a low level of satisfaction (mean of 3.47).

Both the variables of *satisfaction with the display or presentation of the information* (Q27) (mean of 3.87) and the *satisfaction with search effectiveness* (Q29) with a mean of 3.42, showed a general tendency towards a high level of satisfaction.

5.3.1 Combined variables

Let us now look a little bit deeper into these problems and try to understand our user group characteristics and thereby gain a better understanding of where the difficulties stem from. We will examine a combination of variables to see if there is any relation between them. We used the quantitative data on the individual level concerning one variable and compared that with data from the same subject for another variable by using the Pearson correlation (*r*). Due to the low number of participants (38 subjects), it was suggested that these correlation may be interpreted as indications for a relation between variables, although we have found some significant correlation.

The combined variables were measured in a tabular matrix as follows: on the vertical level we have the low or high ratings for variable 1 and on the horizontal level, we have the low or high score for variable 2. The individual ratings on the 1-5 point Likert scale were placed within nine cells for the two variables; e.g. a subject score of 3 for variable 1 and a 5 for variable 2. This led to the score field in bold type in our example.

5.3.2 Previous experience

The only correlation found, when comparing the variable previous experience with other variables was between previous experience and IR knowledge. This will be further examined in section 5.3.5. Surprisingly, we found no significant correlation between previous experience in information seeking in hypertext information systems and the *satisfaction with navigational support to complete an information seeking task* (r=0.17). One might think that previous experience could make it easier to navigate in a new system.

5.3.3 User satisfaction with the search result

We found that the general level of user satisfaction with the search result was correlated to several other factors. We found a correlation (r=.71) between satisfaction with the search result and *satisfaction with information usefulness* (Q23). The subjects with a high level of satisfaction with the search result also had a high satisfaction with information usefulness (Table 14:1). This means that, if we want to increase satisfaction with the search result, we would also need to increase the level of satisfaction with information usefulness, and therefore we would need to know what problems the users had. This will be further examined in chapter 5.5 as REQ3.

Not surprisingly, we also found a correlation (r=.76) between users satisfaction with the search result and user *satisfaction with system effectiveness* (Q29). Those who had a high satisfaction with the search results also had a high level of satisfaction with system effectiveness (Table 13:2). Finally, we found a (weak) correlation of r=.56 between satisfaction with the search result and navigation support to complete a task. Both these correlations tells us that if we want a effective system and that the information is useful for the users, the users need to be satisfied with the search outcome. Also, the support to navigate have some importance for the search outcome here (see 5.3.4 below).

Table 13. Comparing low or high satisfaction with search result (LS v HS) with low or high satisfaction information usefulness (Luse v Huse) (13:1); and low or high satisfaction with effectiveness (Leff v Heff) (13:2).

Table 13:1

HS	0	4	13
	5	1	3
LS	8	0	1
	Luse		**Huse**

[N=35]

Table 13:2

HS	0	0	17
	3	3	3
LS	6	3	1
	Leff		**Heff**

[N=36]

5.3.4 User satisfaction with navigation support to complete an information seeking task.

Support for navigation within the information space in order to complete an information seeking task plays an important role when designing a user supported interface. In our study, we observed that the variables of domain knowledge, search effectiveness and search result correlated with the level of satisfaction with navigation support to complete a task.

A correlation (r=.56) was found between satisfaction with navigation support to complete a task and *satisfaction with the search result.* Users with a low level of satisfaction with navigation support, also scored low satisfaction with the search result (Table 14:1). If we would like users to be satisfied with their search result, the system must provide good support for navigation within the system for the users, i.e. support for finding your way in the system etc. The redesign must aim at supporting those factors that could improve low navigation and low satisfaction with the search result. This means that, not only the search mechanisms, but also the support for finding one's way within the information space are important. The factors involved are further examined in chapter 5.5 as requirement 6.

A correlation was also found between the level of satisfaction with navigation support for completing a task and the level of *domain knowledge* (understanding the domain terminology, Q25). The correlation was r=.50. This indicates that domain knowledge is important for and influence the ability to find the way through the system when performing an information seeking task (Table 14:2).

We also found a correlation (r=.58) between the level of satisfaction with navigation support and the *satisfaction with search effectiveness* (Q29), (Table 14:3). Users who experienced that they received navigation support when performing their task, also experienced a high level of search effectiveness. A low satisfaction with navigation support within the system will therefore affect the satisfaction with search effectiveness negatively.

There was no correlation between the level of *IR knowledge (Q15)* and the level of satisfaction with navigation support to complete the information seeking task (r=-.04). However, we observed that 21% of the subjects had scores for low navigation support and high IR knowledge (not in table 14).

Table 14. Comparing low or high satisfaction with navigation support for completing a task (LNav v HNav) with low or high satisfaction with search result (LS v HS (14:1); low or high domain knowledge (Lterm v Hterm) (14:2); and low or high satisfaction with task effectiveness (Leff v Heff) (14:3).

	Table 14:1				Table 14:2				Table 14:3		
HNav	2	2	13	***HNav***	0	1	16	***HNav***	1	1	15
	1	5	3		0	1	8		2	3	4
LNav	5	2	1	***LNav***	3	1	4	***LNav***	5	1	2
	LS		**HS**		**Lterm**		**Hterm**		**Leff**		**Heff**
			[N=34]				[N=34]				[N=34]

5.3.5 IR knowledge

Different users and user groups have varying IR knowledge (e.g. query formulation and how to use complex search functions).

The only (weak) correlation found, was between IR knowledge and the level of *previous experience* (r=.43) (Q14). This means that those with a high IR knowledge correlated with high previous experience. It also shows to that users with low previous experience also have low IR knowledge (Table 15:1). This could be interpreted as that subjects acquire IR knowledge through experience and learning. By acquiring experience of information seeking in hypertext environments, users thus increase their general IR knowledge. No correlation was found between IR knowledge and *satisfaction with search result* (r=-.04), (Table 15:2).

Also, when looking at the relation between the level of IR knowledge and *the satisfaction with system functionality* (r=.12), we found no significant correlation. At the group level, the ISL group had a 100% score, i.e. a high level for both variables. The score for the CS was 57% and for the Industry group 50%. This suggests that we could distinguish the ISL group as IR experts, unlike the other two groups, which could be categorized as having basic (or medium) IR knowledge. The written data in the open-ended questions were analyzed and are further examined in section 5.5.

Table 15. Relation between low or high IR knowledge (HIR v LIR) and low or high previous experience (LPE v HPE) (15:1); and low or high satisfaction with search result (LS v HS) (15:2).

Table 15:1

HIR	2	3	22
	2	1	4
LIR	2	1	1
	LPE		**HPE**

[N=38]

Table 15:2

HIR	10	5	12
	0	2	4
LIR	1	2	1
	LS		**HS**

[N=37]

5.4 User behaviour - browsing or searching strategy

Examining the users information seeking strategies (browsing or searching), no significant correlation were found with other variables. However, interesting observations were made. Table 16:1, shows that 34% of the subjects with h*igh IR knowledge* wanted to browse and 26% with high IR knowledge wanted to use the search strategy (r=.15), and shows that users have different information seeking behaviours and that both strategies must be supported in the design.

Even though no correlation was found between, *previous experience* and browse- or search-oriented strategies (r=.23), we observed that 16% (6/38) scored for high previous experience and search-oriented information seeking strategy, whereas 39% (15/38) scored for high previous experience and browse-oriented information seeking strategy (Table 16:2). At the group level, 72% of the subjects in the CS group wanted to use browsing. This is further proof for that there is a need for support for browsing.

Another interesting findings are the relations between user *satisfaction with search result* and browsing/searching strategy (Table 16:3). 47% of all those who scored for a high satisfaction with the search result wanted to use a browsing-oriented strategy. Those subjects who scored low satisfaction with the search result, wanted to use the browsing- or searching-oriented strategy equally (45%). We conclude that the system should have more support for browsing, although it seems that users have adapted to the search functions within the system. The above observations indicate that the users had different information seeking strategies and that these strategies must be supported in the interface design, especially browsing-oriented functions.

Table 16. Comparing search/browse strategy with low or high IR knowledge (LIR v HIR) (16:1); low or high previous experience (LPE v HPE) (16:2); and low or high satisfaction with the search result (LS v HS) (16:3).

Table 16:1

Search	1	1	10
	0	3	4
Browse	3	3	13
	LIR		HIR

[N=38]

Table 16:2

Search	3	3	6
	1	0	6
Browse	2	2	15
	LPE		HPE

[N=38]

Table 16:3

Search	5	1	5
	1	2	4
Browse	5	6	8
	LS		HS

[N=37]

To gain more knowledge about browsing and searching from our collected data, we made two other different studies. First, we wanted to see, on a individual level, what actions the subjects performed and also to categorize these into search- or browse-oriented actions. Secondly, we wanted to test, also on the individual level, the intentions the subjects had regarding the browsing- or searching-oriented strategies against which actions they actually performed.

Table 17 shows the distribution of actions made within the actual system set-up. To extract and identify the actions, we used the database transaction log statistics. They were then categorized and coded as browse or search(analytical)[19] actions. The actions were counted and coded individually. At the general level, 2/3 of the actions performed were coded as search-oriented. Among the search-based actions, the Industry and the ISL group used the advanced query page more often than the CS group. The simple search form is on the first (home) page of the Dienst database and thus accessed first. Among the browse-based actions, the 'ListAuthors', and 'BrowseAuthors' actions were most requested by the subjects. One significant result here is that the 'Describe' action was used frequently by the CS group, but only once by the ISL group. This is further proof for that the CS group is more interested in the full-text content, and therefore employs more browsing actions, while the ISL group was more concerned with retrieving bibliographic information.

Table 17. Types of action in the system performed within the different user groups.

TYPE OF ACTION	*GROUPS*			
(ANALYTICAL)	All	CS	Industry	ISL
SEARCHACTIONS				
Query (simple)	113	52	16	45
QueryNF (advanced)	123	41	27	55
Describe[20]	12	7	5	0
TOTALSearch	248 (68%)	100 (68%)	48 (61%)	100 (71%)
BROWSEACTIONS				
ListAuthors	33	15	6	12
BrowseAuthors	24	9	6	9
ListYear	17	5	6	6
BrowseYear	15	2	7	6
Describe[21]	14	10	3	1
ListPublisher	7	1	1	5
Search	6	4	1	1
Repository	3	1	2	0
TOTALBrowse	118 (32%)	47 (32%)	36 (39%)	40 (29%)
TOTAL	366	147	79	140

Finally, we also wanted to test if there was any mismatch between *what users said that they wanted to do and what they actually did*. Since we believe that different information seeking strategies are used within a session to complete a task, we wanted to look closer at our subjects. To accomplish this, we compared the statements in Q11 with the user transaction log from the system for each user and her actions (Table 18). We found a considerable mismatch between those who intended to browse. Ten subjects who said that they intended to browse, ended up using search actions instead. The reason for this could be that there is too little support for browsing within the system.

[19] See chapter 2.2.2 for an explanation.

[20] In connection with search actions.

[21] In connection with browse actions.

Table 18. Comparison between subjects intentions and what they actually did in their browsing and/or searching strategy.

Information seeking strategy intention	*What subjects actually did (Group/Number of subjects)*		
	Browse	*Browse / Search*	*Search*
Browse Total	I = 1 **1**	CS = 4; I = 1; ISL= 3 **8**	CS = 5; I = 1; ISL = 4 **10**
Search/Browse Total	**0**	CS= 1; I = 2; ISL= 1 **4**	CS = 1; I = 1; ISL = 1 **3**
Search Total	CS = 1 1	I = 1 **1**	CS = 2; I = 2; ISL = 6 **10**

[N=38]

The current user interface to the database forced some of the subjects, especially within the CS group, to perform other information seeking strategies (combined browse/search and search) than were planned from the beginning.

5.5 User requirements elicitation

One of our goals was to establish a set of requirements that could guide the redesign of the user interface/system based on data from the evaluation. To do this we developed a method to extract data for this task. Three data collecting methods were used in our study: questionnaire and Likert scale ratings; questionnaire and open-ended questions; transaction log statistics. We then selected variables that we wanted to follow up closer (Table 19) from our study in sections 5.2 and 5.3.

Table 19. Selection of variables for requirement elicitation

REQ	*Variables*	*REQ*	*Variables*
1	Expectations before using the system	5 5.3.5	(H) IR Knowledge and (L) Satisfaction with system functionality
2	Expectations after using the system	6 5.3.4	(H) Satisfaction with search result (L) Satisfaction with navigation support and
3 5.3.3	(L) Satisfaction with search result and (L) Satisfaction with information usefulness	7 5.3.5	[H] IR knowledge and [L] Satisfaction with search result
4 5.3.4	(L) Satisfaction with navigation support and (L) Satisfaction with search effectiveness		

We then performed a qualitative analysis on an individual level for both single variables and combined variables, concerning stated requirements made in connection to the variables respectively. They were categorized and coded into a matrix (Table 20) as follows: the first column contains a list of requirements concerning the information objects, the database search engine and indexing as well as the database structure. The list of requirements are coded into simple words or phrases to describe the function needed. The second column contains the different variables selected as described in table 19. Note that this column does not measure how many times a certain function has been requested. Each function that has been requested has then been marked in the appropriate variable column. In the last column to the right, we have indicated if the required function is or is not present in the system.

Table 20. User requirements

Requirements	*Variables*							*Present*
	1	*2*	*3*	*4*	*5*	*6*	*7*	*in system*
Database collection description (other types of objects)	x	x	x	x		x	x	no
Full-text documents	x			x				yes
List of all reports	x	x						yes
Reports from other sites	x							yes
Bibliographic references	x							yes
Keyword list (Controlled vocabulary)	x	x	x	x	x	x		no
Subject classification		x	x	x	x	x		no
Combined field search			x		x			no
Phrase search					x			yes
Adjacency operator.					x			no
Full-text search			x					no
Combine separate searches				x				no
Better truncation description					x			no
Personal relevance ranking option							x	no
Proximity search	x							no
Fielded search	x							yes
Better instructions and examples of query syntax		x			x	x	x	no
Better error messages				x	x			no
Numbers of items/ references			x			x	x	no
Time coverage/last update			x	x		x		no
Dead hypertext links			x	x				-
Too much text in help pages						x		-
An order form	x							no
More available sites		x						no

Our table can now be interpreted in two ways. First, we can look at which factor or function is most required and then let this guide us in the redesign of the user interface. In this case (the "horizontal" level) it would be database collection description, keyword list and subject classification. Secondly, we can look at specific variables (the "vertical" level) and see which factors the subjects had problems with. This means that if we want to improve, let say, the satisfaction with support for navigation to complete a task, we should look closer at the variables 4 and 6. These will point us to some basic and important factors that need to be considered in the redesign. Table 21 deals with the aspects of the variables of IR knowledge and navigation support and satisfaction with navigation support. Earlier, we found evidence that there were groups with different levels of IR knowledge (experts and novices). In table 21, we have listed variables 5 and 7 that relate to IR knowledge, and variables 4 and 6 which relate to the satisfaction with navigation support. If we focus on these two combined variables and then extract the functions mentioned by the subjects, we would get the following list of requirements useful for an interface redesign:

Table 21. Requirements concerning IR knowledge (5 and 7) and satisfaction with navigation support (4 and 6)

Requirements	*5*	*7*	*4*	*6*	*Present in system*
Database collection description (other types of objects)		x	x	x	no
Full-text documents			x		yes
Keyword list (Controlled vocabulary)	x		x	x	no
Subject classification	x		x	x	no
Combined field search	x				no
Phrase search	x				yes
Adjacency operator	x				no
Combine separate searches			x		yes
Better truncation description	x				no
Better error messages	x		x		no
Personal Relevance Ranking option		x			no
Better instructions and examples of query syntax	x	x		x	no
Time coverage/update			x	x	no
Numbers of items/ references		x		x	no
Dead hypertext links			x		-
Too much text in help pages				x	-

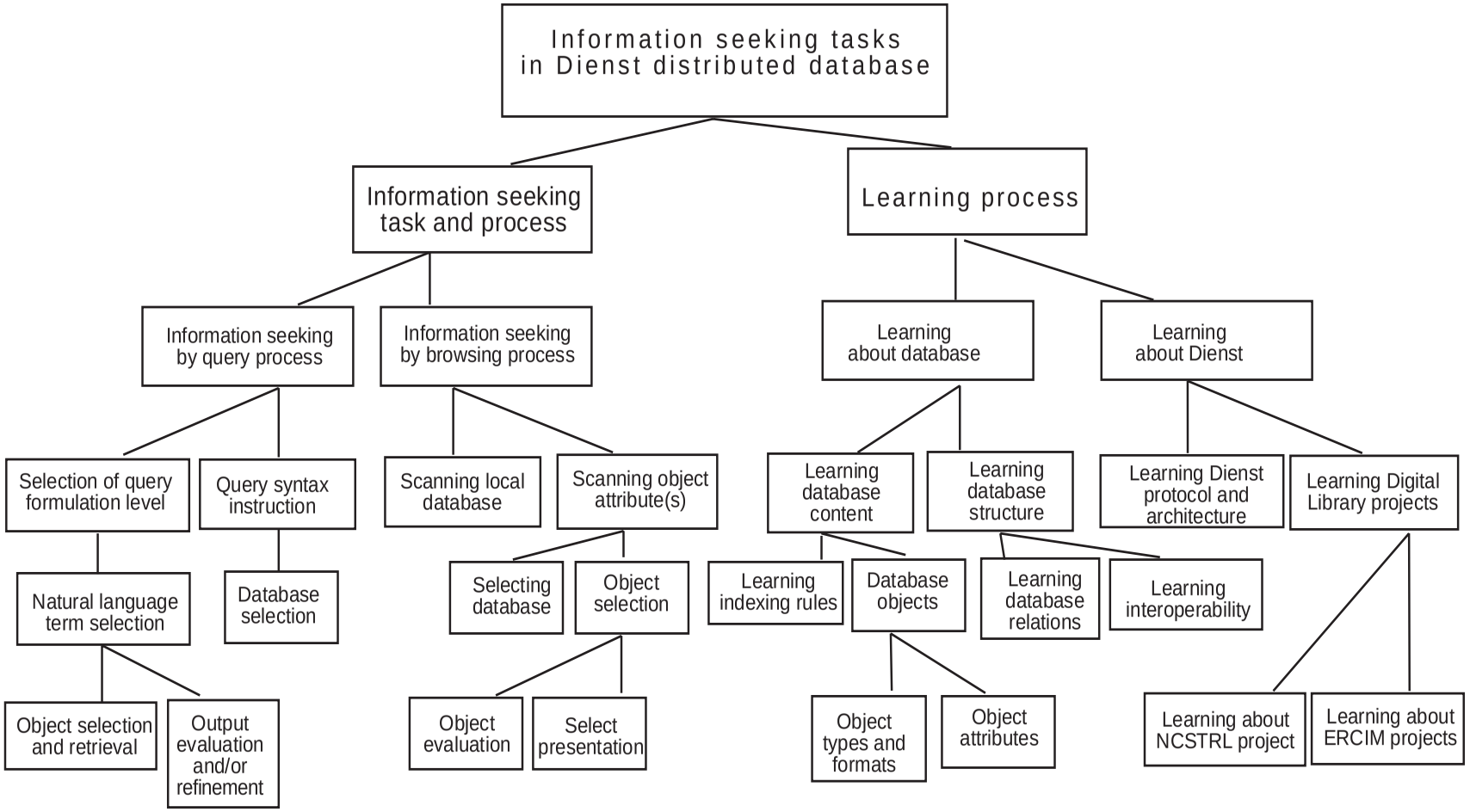
Table 21 shows a list of functions that reflect the subjects needs, requirements and expectations that must be taken into consideration in the redesign. We see that many of the requested functions deal with the search functions, possibilities to modify requests and information about the database. This way, the list of requirements needed create an interesting "map". When analyzing table 22, we found that some of the functions had been requested more than others. We believe that if we could enhance the user interface with (some of) these functions, we also would provide better support for the users.

5.6 Task Analysis - HTA

As described din section 2.3, we applied a basic hierarchical task analysis (HTA) as a tool for generalizing and describing the users tasks offered by the system. The framework is constructed like a tree structure, beginning with a very general task. We categorized at a general semantic level the tasks and sub-tasks offered in the system. The "map" of different tasks can be seen in Figure 5 which offer us a graphical means of navigating through this hierarchy of tasks.

Our task analysis in Figure 5 describe an abstract structure of tasks and offer us a formal way to describe what the system offer the users when performing a information seeking task. They can be divided in four general classes or categories of activities: information seeking through searching; information seeking through browsing; learning about the database components and structure; and learning about the system in general and its context. At a general level the tasks corresponds to actions within the system. Furthermore, the task analysis do not distinguish between task that are interface-related or tasks that are system-related. One problems found using the HTA method is that it does not tell us the "horizontal" connections between browsing and searching strategies.

Figure 5. Hierarchical task structure of activities offered by the system (See next page)


Information seeking tasks in Dienst distributed database
Information seeking task and process
Learning process
Information seeking by query process
Information seeking by browsing process
Learning about database
Learning about Dienst
Selection of query formulation level
Query syntax instruction
Scanning local database
Scanning object attribute(s)
Learning database content
Learning database structure
Learning Dienst protocol and architecture
Learning Digital Library projects
Natural language term selection
Database selection
Selecting database
Object selection
Learning indexing rules
Database objects
Learning database relations
Learning interoperability
Object selection and retrieval
Output evaluation and/or refinement
Object evaluation
Select presentation
Object types and formats
Object attributes
Learning about NCSTRL project
Learning about ERCIM projects

5.7 Discussion of results

The evaluation of the hypertext IR system (Dienst), provided us with interesting and valuable information about the problems involved in understanding information seeking behaviour, and thus the issues relevant for user interfaceredesign.

Our goal with this study, was to gain some knowledge of the characteristics of the users' interactions and their behaviour with the actual system, and finally, to see where this would lead us in the implications for a redesign of the interface. A central issue in this study has been to analyze the users' information seeking behaviour and needs, and to see if and how this knowledge could be integrated in the user interface design. For our evaluation purposes of the IR system we have stated why we wanted to evaluate the system and user interface; determined the setting for our data collection; determined the variables to be examined; and determined a set of data collection methods by which the variables could be analyzed.

5.7.1 Methodological results of the experiment

Concerning our *first* question (section 1.3), we found that it was possible to perform an experimental WWW-based evaluation as part of the design cycle to create empirical quantitative and qualitative data. Our evaluation experiment and methods provided us with valuable data to better understand some of the problems within the area of information seeking behaviour and user interface design. Based on our evaluation experiment, the following observations were made:

- Our approach to an WWW based evaluation study was performed in a real setting and situation and created real empirical data to be evaluated and showed that it was possible to conduct an experimental WWW-based evaluation as part of a design cycle. Results were obtained from analyzing the information seeking behaviour of real users, with actual and real-life needs rather than studies of users in a laboratory setting. This method is especially suited for iterative interface design tasks and decision. However, to get more reliable data sets, we need a larger user population.
- No interference from other users or the evaluation team were made during the evaluation task.
- The questionnaires could be distributed both world-wide or focused on a small group of subjects via e-mail. The questionnaires were also easily managed and administrated in an online setting and the subjects had easy access to the database through WWW. One lesson learned was not to ask too many questions. It is better to focus on a few factors to be examined, at least in a study at this level. This because users do have time constraints and motivation problems. It is easier to get questions answered at the beginning of a session than at the end.
- The feedback received resulted in a complex set of data to be evaluated. Although the analysis phase was time consuming, it was well worth the results since the data set also can be used for other studies. Finding automatic ways to analyze and present the data would help in the future. For a future task, such tools could be connected to the database log or other data collected from an evaluation like this.
- The combination of qualitative and quantitative data collection methods has been fruitful. Statistical data from the questionnaires (Likert scales) and transaction logging, together with data from the questionnaires (open-ended comments), provided a rich "map" of data. Furthermore, these different subjective and objective sets of data could be combined in various ways to extract information.
- Planning of the analysis is important. Questionnaires create a large set of data. Data collection, analysis methods and designing a matrix for the data have to be planned. Quantitative and qualitative data need to be treateddifferently.
- Transaction logs only provide information about what the users did using different commands, and not what they thought nor their personal feedback. What we can observe, is patterns of movements within the system. Transaction log statistics provide a means of collecting data over a long time period, but are insufficient for answering complex questions.

- The HTA is a valuable tool for distinguishing tasks and gave us a mean to describe and structure the tasks given by the system at a formal level. We then used this formal "map" to compare with the analysis of the users and their statements. Although this provided us with interesting findings (see section 5.7.5), we should also, in the future, consider the possibility to make a task analysis of users information needs as formulated and observed when performing a information seeking task. This could be done using methods like Cognitive Task Analysis or Cognitive Walkthrough.

5.7.2 User preferences, knowledge and expectations

To answer our *second* question (section 1.3), we examined users' preferences, knowledge and goals and expectations when performing an information seeking task in an hypertext IR environment.

- Our study showed that the subjects had different educational and professional backgrounds.
- The study shows that there are differences in users goals and tasks in their information seeking activity. The most frequent goals were: finding information to write a paper/thesis/report, gathering information for a project, and learning about the database content and topics. We also found that the subjects described their tasks in a number of ways and employed different means to accomplish their goals. Furthermore, a first attempt to distinguish different contexts, in which the user's tasks originated. These contexts should influence the user when performing the information seeking task. A simple categorization include: the individual (or internal) context level, the group context level, and the community level.
- We found differences among the subjects concerning preferred information seeking strategy: the CS wanted to browse; within the ISL group there was a subgroup which preferredsearching. This should have implication for a redesign of the system and it should better support browsing activities since this was missing.
- Users stated that they had high previous experience with information seeking in hypertext environments. Based on this result, there is no need for further guidance or explanation of the hypertext system.
- We also found that subjects also had a basic IR knowledge. However, although the users have a basic level knowledge on how to pose queries, we could identify differences between groups: one group with medium IR knowledge or novices (CS) and one group of IR experts (ISL).
- Users had expectations before entering the IR system, manifested as requiredfunctions. This points to that users have built internal mental models[22] of IR systems and based on them they have individual expectations of the system acquired through experience with different IR systems. Our study resulted in a list of functions that the users expected to be present in the system and these provided us with valuable.
- Users learn the system. Though analysis of the subjects, we found that one part of the IR interaction involves a learning process. Comparing the expectations before and after using the system gives us an indication of what the user has learned through experience of the actual system. This is true concerning both the database structure and content during the information seeking activity.
- Users have problems in identifying or recognizing functions when interacting with the system. It should be clear to the user which functions are present or are not within the system. These identified problematic functions must be designed so as to be recognized by the user and those not recognized, but present, should be enhanced.

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[22] People have different views of the world, of themselves and of the tasks and activities that they are doing. These views could be regarded as models that people have of themselves and of things and other people when interacting with them. These models could provide explanations for understanding the interaction between, like in our case, the user and the system.

5.7.3 User satisfaction

In our *third* question (section 1.3), we examined the users satisfaction in terms of a number of *single variables.*

- No significant result could be found on the general level, concerning *satisfaction with the system functions*, although the most satisfaction was found within the ISL group, who could be considered to be experts. The Industry group had problems deciding their satisfaction with the system functionality, and could therefore, from our point of view, considered to be novices or at least to have problems understanding the functions of the system. This suggests that the search functions must be made clearer and more differentiated for the user. Descriptions and explanations, and also visual display features as an option for the user could be solutions.
- A significant high level of *satisfaction with terminology understanding, system overview, information display* and *finding information effectively* was found among the subjects.
- One reoccurring problem, was that different users (and groups) had difficulties in deciding whether they were satisfied or not with specific functions. This could mean that the subjects lacked sufficient knowledge to make a judgement in the specific situations. This was most significant in variables like satisfaction with the search result (especially the CS group), satisfaction with search functions (Industry group), and satisfaction with navigation support to complete a task (CS group). These problems should be considered and supported in the user interface redesign. We therefore suggest that there should be a better display of functions and mechanism. We also found differences between user groups. The ISL group could be regarded as experts since they clearly stated why they did like or not like their search results and the CS group as novices since they had most problems with judging their search results.
- When examining if the reason for low *satisfaction with navigation support*, was related to a time or action factor, we found that it was time related, rather than action-related, in the sense that the subject who was satisfied spent more time in the system than those who were dissatisfied. This suggests that we have different levels of time thresholds. However, looking closer at the average actions made, we can see that those with low satisfaction had less time between every hypertext "click" and acted as if they were scanning their way through the system.
- Looking at the *satisfaction with information usefulness*, we found, on a group level, that the Industry group scored for low usefulness. Their retrieved items did not match their needs. Since this issue is related to relevant topics, it shows that the subjects maybe should be informed early on about the content and topics within the system.
- The variable of *satisfaction with navigation support to complete a task* showed ambivalent attitudes and difficulties among the subjects in deciding the level of satisfaction. Especially the CS group had a high rating of point 3 (Likert scale) and can then be categorized as novices. The ISL had a high level of satisfaction for navigation support and could be categorized as experts. Since many within the CS group wanted to browse and that our system is search-oriented, we must conclude that the CS group was poorly supported and that we need to focus on more browse-oriented support. When examining the subjects on a individual level, we found that those with low satisfaction and "undecided" (points 1-2 and 3), made browse-related (CS group) comments and search-related (ISL group) comments. This reflects differences between groups and users regarding preferred information seeking strategies. Navigation also deals with clarity and 'wayfinding', in the sense that it should be easy for the user to understand how to find her way and to understand the functions and the information objects in the information retrieval environment. A solution for this navigation problem could be to provide one page mechanism that the user could manipulate and control rather than the "jumping back and forward" mechanism that is offered in the WWW environment.

Results from the *combined variables*

- Examining the variables, we found that the level of satisfaction with search result correlated with the satisfaction with information usefulness and with system effectiveness. Satisfaction with navigation support to complete a task, had a positive correlation with satisfaction with search result, domain knowledge and search effectiveness. This means that the level of satisfaction with navigation support has important

implications for other variables, and must therefore be considered in the user interface design. This is further proof for the importance of supporting different information seeking strategies so that different users can achieve a high satisfaction with the information seeking task.

- We also saw that people expected a specific function, but when performing their task, they did not use that function.
- Concerning IR knowledge, we only found a correlation with previous experience with information seeking in hypertext environments, which suggests that professional skill, learning and experience of using IR systems seem to be related to IR knowledge e.g. query formulation. Even though no correlation was found between IR knowledge and satisfaction with the search functions, we found that on a group level, the ISL group had scored 100% for both a high level of satisfaction with IR knowledge and for system functionality. This strengthens our assumption made before that we have a group that could be categorized as novices or with medium knowledge and a group of experts. This means that if we want to support IR knowledge novices, we must provide means for this in the user interface.

Browsing and searching strategy

- On a general level, no significant result was found. However, at the group and individual levels, we made some interesting observations that could influence the redesign. Subjects with a high level of IR knowledge, wanted to use either browsing (34%) or searching (26%) strategies, while 40% used both strategies. We also found that there was a mismatch between what subjects said they wanted to do and what they actually did. This was especially true for subjects who wanted to browse, but ended up in searching instead. We also observed that a high level of those with high previous experience wanted to use searching functions. At the group level, we observed that almost 50% of those who were satisfied with the search result turned to browsing. Of those with low satisfaction with the search result 45% wanted to use either browsing or searching strategies. To conclude this means that supporting different information seeking strategies is important. It also suggests that the search mechanisms offered to the users should be enhanced. We also observed that those who wanted to browse ended up with a combined browse/search and search strategy. The current interface "forced" the users to interact with the system in a specific way and to perform other strategies than they originally had planned. In summary, the interface gave the user poor control over the interaction, who desired a greater variation of information seeking actions.

5.7.4 User requirements

In regards to our *fourth* question (section 1.3), we wanted to extract a list of requirements based on answers from the open-ended questions. This question is partly answered in this section and partly in section 6.1.

- The method of establishing a requirement list, based on extracted data from the open-ended answers made by the users, gives us the opportunity of creating a protocol of functions important to the user. This gives us an interesting "map" of requirements and it can be measured in various ways (i.e. on the horizontal or the vertical level). This additional method is, together with the other methods used, valuable for pinpointing out single factors leading to knowledge about the subjects behaviour and their needs.
- Our analysis of the requirements made in connection with the variables of IR knowledge and navigation support, resulted in a set of factors important for the system redesign (user interface). If we categorize the requirements, we find that most of them belong to query formulation and search functions, but also include requirements for information about the objects in the database.
- These exploratory observations illustrate the need for real user observations in real environments to pinpoint important issues and to discover "hidden" realities. Even though we managed to gather information concerning requirements and needs important for the redesign, we did not acquire knowledge about *how* these changes should be done in the interface. This will have to be evaluated in future studies.
- To conclude that the interface redesign involves two tasks: 1) we need to make some of the functions within the system more recognizable to the users, and we need to implement a group of functions not in the system,

but highly required by the users; 2) we need to provide means for the user that support different information seeking strategies. We believe that if we could enhance the user interface with (some of) these functions, we would also provide better support for the users. This will be subject for future research.

5.7.5 Task analysis

When comparing the task analysis and the analysis of our users, we found that the user interface did not support the browsing and combined search/browse activities enough. Furthermore, it shows that there are considerable learning tasks offered. We found that there are components missing in the system such as subject lists. We also saw that users had problems moving between tasks, for example between searching and browsing tasks and learning tasks. The analysis also gave us the possibility to check how users organized their working tasks and how it mapped to our formal structure of tasks within the system (see section 6.1).

6. User interface design

One of our tasks in this study was to see if was possible to gather information and results that could be used for a redesign of the user interface to the Dienst database. Since computer applications can be highly complex, the design of effective human-computer interfaces is very important. One task for the design of user interfaces would then be to cope with and to reflect the users tasks of seeking information and their behaviour through consideration of users knowledge and goals. Recent studies (Koenemann and Belkin, 1996) show that when the end-users are given more instructions and more control over their searches, this affects their satisfaction and performance in a positive way. This will then obviously be an issue for the user interface design for any successful system.

6.1 Implications for user interface design

When designing a user interface, we have to make some decisions in order to improve the user interface in some particular direction. In our study we have based these decisions on the results from user preferences, user satisfaction, user tasks, user behaviour and user requirements. It should also be noted that our mission is not to make a new interface design, rather to extract factors important for the user interface design. It is up to a design task to implement a new design based on the finding obtained in this study.

In our study, we have identified several important factors, important for user interface redesign in general and for our system in particular. It should be noted that the results and the following conclusions mainly concerns computer science domain, but the implications drawn could represent important factors to be considered for IR design in general.

The evaluation:

- For the evaluation methodology purpose, we could use a visualizing tool, such as Spotfire (Ahlberg, 1996), to automatically gather, process and monitor transaction log data and visually display the results. This could be done on both an individual level and on a general level using different time parameters. Since it is possible to manipulate the parameters, the tool could be used to enhance and formalize an evaluation task. We could then assign different parameters to the tool to be examined and analyzed.

User background preferences:

- *Previous experience*. Users stated that they had basic experience with searching in a hypertext WWW-based information system. This means that there is no need to provide further instructions for this set of users.
- *User expectation*. We found that users do have expectations. These expectations are based on earlier experiences acquired through experience with different IR systems and reflect the users mental model of an IR system. This shows that the fact that users come from different information seeking environments. One solution could be to implement not just different interfaces to an IR system, but also maybe to consider implementing different IR techniques to adaptively and interactively support various needs and information seeking strategies within a single or multiple IR system(s) framework.
- *User tasks and goals*. We found that users had a variety of goals when entering the system, including learning the system. Generally, the redesign should take into consideration the goals stated by the users and the tasks analyzed, which can then be adopted by the system. More specifically, the interface solutions should be to give the user goal- or task-based options where the user could specify or define their task. According to what the user defines, the interface should be able to adopt to that task. The study also showed that there are different context environments, in which the user's tasks originated. We assume that these different environments influence the user when performing the information seeking task, and consequently, we should take in account the fact that people have different of working context and probably also move dynamically across several context 'spaces'.

- *Recognition and identification*. We found that user had problems in identifying functions within the system. There could be two reasons for that: either the user did not understand the meaning of that particular function, or could not find that function in the interface. Generally, functions within the system should be more visible and easier to understand. Specifically, one solution to this could be to provide a "map or guide" of all main functions within the system. This could be a dynamic "window" within the search page or could be a separate window supporting the search interface.
- Our study methods detected two design aspects: one level where we need to implement new functions and that we need to improve already existing functions due to the problems of recognition or lack of identification. Secondly, we need to provide means for the user that support different information seeking strategies.

User satisfaction:

- *Browsing and searching*. There was a strong tendency towards browsing, and the system should therefore be enhanced to better support both browsing and the combination of search/browse activities. When examining what users said they wanted to do and what they really did, we found that users that wanted to browse had limited possibilities to do so and that they were "forced" to execute search actions. One result of this could be that the user did not have control over the interaction since they were doing things they did not have any knowledge or experience about. We found differences among the subject concerning preferred information seeking strategy: the CS wanted to browse and within the ISL group there was a subgroup who preferred searching. We also found that 50% of the users used a combination of browse and search actions. One of the reasons could be that they wanted to retrieve different types of information (full-text documents or bibliographic references), which should be supported. In summary browsing is poorly supported and since the interface "forced" the user to perform searching, we need to support for different information seeking strategies in order to let the user have more control over the interaction. Another solution could be to make a separate page with a combined search/browse interface.
- *Novices vs. experts*. We found evidence that there are users with non-expert knowledge as well as subjects with expert knowledge, e.g. concerning IR knowledge. To cope with different levels of knowledge, we could offer the user only one page, showing a basic set of options. On this page there could be "hidden" areas with information or functions that are dynamically visualized when activated. Ultimately, these different knowledge levels should be built into a user model, that in some way recognizes or suggests an interface level for the user.
- *Support learning*. We also found that, when using the system, the subject did go through a learning process. When the user were finished with the task, she had stated other expectations. We also noticed that subjects requested enhanced instructions for how to formulate queries and information about syntax. This points out that users build on their experiences and knowledge, and leave the system with new knowledge about our system specifically, and IR systems in general.
- *Decision problems*. We found that users had problems in deciding the level of satisfaction with certain functions within the system such as: search results, search functions, and navigation support. One reason for this was that those subjects that wanted to browse, ended up in searching, due to the limited support for browsing. Another reason could be that the amount of feedback, both concerning the performance of the search and the result, was not satisfactory. A third reason may be that the user did not have the knowledge to decide if the results, functions or navigation were satisfactory or not. This means that the users need support to avoid the state of "uncertainty".
- *Level of control*. One of the main characteristics of an IR system is the degree of interactivity. By this we mean the level of control we give the user when performing a task and making decisions during the information seeking interaction process. To support different levels of knowledge and user groups like novices and experts, we could provide different interaction levels implemented in the user interface. One thing that we could see in our study was that users wanted to have a rather high degree of control. We could see that they did learn about the system and that they used their previous experience in judging both the system

performance and the result outcome. This shows that the interface in some way has to adopt to the individual differences and also to differences within the user groups.

- *Navigation*. As mentioned earlier, the issue of navigation and to navigate in 'information spaces' is getting more attention, especially within hypertext/media environments such as WWW. One general observation was that even though many users were dissatisfied with the functions and support within the system, they were at the same time very positive about the system performance. This problem could be understood as a) a navigation problem, which reflected the users' need for tools and support in their information seeking tasks; and b) an adaptation problem, that is how the system should adapt to users' preferences in order to offer better support. The variable of satisfaction with navigation support to complete a task showed difficulties among the subjects in deciding the level of satisfaction, especially in the CS group. If we consider that the CS group wanted to browse and that our system is search-oriented, we must conclude that the CS group was poorly supported within the system. When examining the subjects on a individual level, we found that those with low satisfaction and, made comments that were browse-related (CS) and search-related (ISL). This reflects that there are differences between groups and users. Navigation also deals with clarity and 'wayfinding', in the sense that it should be easy for the user to understand how to find her way in an information space or information retrieval environment.

User requirements:

- The study of open-ended questions resulted in a list of requirements concerning different aspects of the system. These requirements reflect the users expectations, knowledge and experience. Regarding the aspects of navigation support, the following functions need to be implemented or improved to enhance the usability of the system and the satisfaction level of the users to navigate in the information system space: the database collection description; keyword list; subject list and classification; time coverage and database update. Concerning the level of IR knowledge, we found that better instructions for query syntax formulation were needed. We also saw that some of the functions asked for were actually present in the system. This needs to be considered in the redesign of the system. Finally, we have seen that there are functions that need to be implemented (not in the system) and that there are other functions (present in the system) that need to be treated to improve the function usability.

Task analysis

- *Mediate communication*. Concerning our task analysis, we want to point out one interesting observation. When comparing the user requirements (table 9) and with our task analysis, we saw that users expressed that they wanted to communicate in several ways. Statements like: to make recommendations for customers and to establish contact with other researchers, indicates that there is a need for tools and ways to collaborate and communicate.

7. Conclusions

People working within an electronic environment, especially with an information seeking task, are involved in activities which deals with cognitive problems like navigation, identification, and evaluation of information objects as well as understanding different information systems and their functions.

This thesis describes an exploratory evaluation of an IR system user interface, of the Dienst system, a WWW-based IR system implemented in a real-world online WWW setting as well as investigating information seeking behaviours. We used an unorthodox interdisciplinary approach involving methods from both HCI and information science research. For the study purpose, we used a networked (WWW) and distributed document database (Dienst), containing a set of Swedish Institute of Computer Science (SICS) research reports within the computer science area. The objective of our study was:

- to perform an experimental WWW-based evaluation of the information seeking interaction in an hypertext IR system and to investigate if the current user interface to he Dienst WWW-basedIR system provide sufficient support in order to conduct an information seeking task
- to identify and describe characteristics of the user population
- to make suggestions for supporting user characteristics and needs in the user interface redesign

Our underlying assumption was that it was possible to perform an experimental WWW-based evaluation as part of the design cycle to create empirical quantitative and qualitative data using data collection methods like online questionnaires, open-ended questions, database transaction log statistics and task analysis.

The methods used in our thesis are based on an interdisciplinary approach which combines both the IR interaction perspective and the user-centered design methods in HCI. We implemented the study in an experimental real-world online WWW setting and collected empirical data i.e. cognitive and traditional statistical data sets from users performing an information seeking task using a combination of both qualitative (questionnaires) and quantitative (transaction logs) data collection methods. Finally, we analyzed collected data according to how users interact with the information system in order to make suggestions for a redesign of the user interface. As a general result of our study, we have observed several levels of work that must be understood in order to understand information seeking in a context:

- The task environment (including work-task, information seeking task and task offered by the system to support information seeking)
- The users specific goals and tasks contexts
- The users information seeking behaviour
- The use of an IR system and its components, including the user interface

Since IR systems deals with human information needs, and the IR system user interface gives the user the level of control to satisfy this need, we have to examine the factors behind those processes. In order to answer our research questions, we will now summarize our findings. We found that it was possible to perform an experimental WWW-based evaluation as part of the design cycle to create empirical quantitative and qualitative data using data collection methods like online questionnaires, open-endedquestions, and database transaction log statistics. This method is especially suited for iterative interface design tasks and decisions, but also for monitoring individual information seeking behaviour within a specific situation (limited time), as well as over a longer time period, based on specific user tasks or user behaviour.

Cognitive data that deals with both the users knowledge, experience and expectations and how users cope with their information problem and interact with the IR system and its components (including the user interface), are very important for the understanding of the users problems regarding information seeking. This includes the understanding of how users interact with the user interface. In our study, we collected data on user preferences and backgrounds which showed that there are differences among the subjects. We also found evidence that there were non-experts and experts, both individually and groups which neededto be considered regarding factors like IR

knowledge. We provided a "map" of user goals that could be observed, showing large variations in purposes for the information seeking activity.

Furthermore, through our exploratory study we found interesting results that point to important considerations concerning the users information seeking behaviour. As a result of the study we recognized a set of aspects or factors influencing the information seeking task, aspects that should be supported in the user interface design.

We found that the IR interaction involves that the users are *learning* the system and that they have different *expectations* of the system. We observed that people expected a specific function, although when performing their task, they did not use that function. These different levels of knowledge should be supported in the user interface design. The study also showed that interacting with a information system is a problematic situation where users had difficulties *identifying or recognizing* functions within the system. Another, reoccurring problem found was that different users (and groups) had problems in deciding whether they were satisfied or not with specific functions. Furthermore, as a consequence of the recognition and could not decide problems mentioned, a solution would be to make a better support for *navigation*. Users have different *tasks and goals*, and our feeling is that it is very important to support these. The study also showed that the user interface should support both *browsing and searching*. We found proof that those who wanted to browse were not taken into consideration and that the current user interface "forced" them to perform search-oriented actions. We also saw that there are users who could be considered as *novices and experts* respectively, and to support them could be done through different *levels of control* at user interface level. Finally, we discovered through our task analysis, that there was a need to communicate with other humans within the system and therefore we need to support the *mediation of communication*.

Interesting correlations were found concerning factors such as satisfaction with navigation support (in relation to satisfaction to the search result and domain knowledge) and satisfaction with search result (in relation to satisfaction with information usefulness and satisfaction with system effectiveness). It should be noted that these correlation should be viewed as indications due to the experimental study setup. We also noted that there was a considerable mismatch between what users said that they wanted to do and what they really did concerning using browsing or searching-oriented information seeking methods. We also managed to create a list of requirements from our set of data. Using a matrix, we listed required functions or needs related to certain aspects of the system.

7.1 Future work

Future IR research should involve a more focused methodological framework for acquiring knowledge of how users, on a general and individual level perform during an IR interaction. This way the design of the IR interface (and system) could be adaptive (Brusilovsky, 1996) and support the users in their information seeking task. This knowledge represents the users thoughts and behaviour and reveals problematic situations that will have to be considered in an IR user interface design. In the longer perspective, this knowledge should, be implemented in the IR system and interface to improve the interactions.

User modeling would be necessary in order to create a better adaptation between user's knowledge, tasks and goals, though this was not pursued in this study. A very interesting and important factor is the issue of different kinds of tasks and how they affect the user behaviour. We have recognized the tasks offered by the system and the user interface and the different levels of tasks (read context) of the users. It seems that more research have to done in this area. In the future, the methodological studies need to be more focused and less exploratory. This study has created some insight in the general problem area of information seeking strategies and IR interaction, but has also shown that there are specific problems underlying the users behaviour when seeking information in a hypertext environment. To support users in their activities is an increasingly important task. Finally, these exploratory observation illustrates the need for real user observations in real environments to pinpoint important issues and to discover "hidden" realities. Even though we managed to gather information concerning requirements and needs important for the redesign, we did not learn *how* these changes should be designed in the interface. This will have to be evaluated in future studies.

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Appendice A : List of Tables and Figures.

List of Tables

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Appendice B : Background question in survey 1 and 2.

Background

Name (optional) :

Email (optional) :

Occupation (optional) :

Other Occupation (optional) :

Education (optional) :

Other Education (optional) :

Appendice C : Table of data : First Survey

Question	***Group***	***1***	***2***	***3***	***4***	***5***	*Mean*	*Subjects*
Q11	***All subjects***	***13***	***6***	***7***	***7***	***5***	***2.60***	***38***
I have a clear knowledge about what I am looking (searching) for.	CS	6	3	2	3	0	2.14	14
1 = No, I am just browsing	Industry	2	1	3	3	0	2.78	9
5 = Yes, I know exactly.	Inf. Spec/Librarian	5	2	2	1	5	2.93	15
Comments : What are your information needs?								
Q12	***All subjects***	***2***	***1***	***5***	***6***	***22***	***4,25***	***36***
I want to see if the information could be useful for me.	CS	2	1	2	2	5	3,58	12
No, I know that it is useful.	Industry	0	0	2	4	3	4,11	9
Yes, I want to scan the system to see if the information is useful	Inf. Spec/Librarian	0	0	1	0	14	4,86	15
Comments: What type of information do you expect to find here?								
Q13	***All subjects***	***25***	***3***	***2***	***2***	***6***	***1,97***	***38***
I search the information for someone else.	CS	10	1	0	0	3	1,93	14
No, I want to use the information myself	Industry	6	1	2	0	0	1,55	9
Yes, I do this search for someone else.	Inf. Spec/Librarian	9	1	0	2	3	2,26	15
Comments: What are the information being used for?								
Q14	***All subjects***	***1***	***5***	***5***	***7***	***20***	***4.05***	***38***
I am used to searching for information in hypermedia systems.	CS	0	3	1	3	7	4.00	14
No, not at all.	Industry	1	1	0	1	6	4.11	9
Yes, I often look for information this way.	Inf. Spec/Librarian	0	1	4	3	7	4.06	15
Comments : What type of information do you look for?								
Q15	***All subjects***	***3***	***1***	***7***	***9***	***18***	***4.00***	***38***
I know how to formulate queries	CS	3	0	4	4	3	3.28	14
No, I just try with what I know	Industry	0	1	1	2	5	4.22	9
Yes, I know how to formulate queries.	Inf. Spec/Librarian	0	0	2	3	10	4.53	15
Comments: Do you think that you need support, and in that case how and what?								

Appendice E : Table of data : Second Survey

Question	*Group*	*1*	*2*	*3*	*4*	*5*	*Mean*	*Subjects*
Q21		**4**	**7**	**8**	**12**	**6**	**3,24**	**37**
I'm satisfied with the search results	CS	1	2	5	3	2	3,23	13
No, not at all.	Industry	2	0	1	5	1	3,33	9
Yes, very satisfied.	Inf. Spec/Librarian	1	5	2	4	3	3,20	15
Comments : What did you expect to find in the system?								
Q22		***2***	***5***	***9***	***16***	***3***	***3,47***	***34***
I'm pleased with the search functions the system offer me.	CS	0	2	3	7	0	3,41	12
No, not at all.	Industry	1	2	4	1	1	3,25	8
Yes, very satisfied.	Inf. Spec/Librarian	1	1	2	8	2	3,64	14
Comments : Which search functions do you need?								
Q23		***6***	***5***	***5***	***11***	***6***	***3,11***	***34***
The retrieved documents and information were useful to me.	CS	2	4	0	5	1	2,92	12
No, they didn't match my information need.	Industry	2	0	5	1	0	2,62	8
Yes, I'm very satisfied.	Inf. Spec/Librarian	3	1	0	5	5	3,57	14
Comments: What kind of information were you looking for?								
Q24		***3***	***4***	***1 0***	***12***	***7***	***3,44***	***36***
There were enough support for navigation to complete my search.	CS	0	2	6	3	1	3,25	12
No, it didn't give any support.	Industry	2	0	1	4	2	3,44	9
Yes, it gave me all support I needed.	Inf. Spec/Librarian	1	2	3	5	4	3,60	15
Comments : What kind of support did you need and in which situation did you need it?								
Q25		***1***	***1***	***3***	***8***	***24***	***4,43***	***37***
I understood the terminology used in the system.	CS	0	1	1	2	9	4,36	13
No, not at all.	Industry	0	0	1	0	8	4,77	9
Yes, I understood it all	Inf. Spec/Librarian	1	0	1	6	7	4,20	15
Comments : What type of terms did you not understand?								
Q26		***3***	***3***	***7***	***10***	***13***	***3,75***	***36***
I got a good overview on how the information system works.	CS	0	2	4	4	3	3,62	13
No, it was unclear	Industry	0	0	1	2	5	4,50	8
Yes, I could identify information and function.	Inf. Spec/Librarian	3	1	2	4	5	3,47	15
Comments : In which way did you find it difficult?								
Q27		***1***	***3***	***5***	***14***	***10***	***3,87***	***33***
The display of the information was easy to understand.	CS	1	1	2	6	2	3,58	12
No it was confusing	Industry	0	1	1	3	3	4,00	8
Yes, the structure/organization was easy to understand.	Inf. Spec/Librarian	0	1	2	5	5	4,07	13
Comments : Which part(s) do you want to change?								
Q28		***2***	***4***	***8***	***13***	***5***	***3,47***	***32***
The combination of text and graphics did help me in my task	CS	2	2	5	2	1	2,83	12
No, it was confusing	Industry	0	1	2	4	1	3,62	8
Yes, it supported me in my decisions	Inf. Spec/Librarian	0	1	1	7	3	4,00	12
Comments: Which part(s) do you want to change?								
Q29		***6***	***2***	***6***	***15***	***7***	***3,42***	***36***
I found my information in a effective way.	CS	3	1	1	5	3	3,31	13

No, it was not effective.	Industry	1	0	1	7	0	3,56	9
Yes, I am satisfied with my search.	Inf. Spec/Librarian	2	1	4	3	4	3,43	14
Comments: What was wrong with your search?								