Review of HCI Research

Focus on cognitive aspects and used research methods

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Abstract

This paper investigates the scientific work within the field of Human-Computer Interaction (HCI) with focus on cognitive aspects. We discuss the overall structure of the field, research methods and some influencing theories and concepts related to cognition. Moreover, we survey the research methods used in HCI literature dealing with cognition related concepts. The results indicate that empirical and non-empirical work is almost evenly emphasized and that most of the empirical research has been experimental.

Keywords: cognitive aspects, human-computer interaction, IS research, human factors

BRT Keywords: AA02, HC01, IB01

Introduction

Research disciplines in general are shaped by a set of philosophical assumptions, which can be revealed by using two questions: “What must be investigated” and “How can the information be obtained”. For example, in the field of human computer interaction (HCI), the area under investigation contains organizational, individual and technical aspects of IS use and development. Moreover, the valid research methods range from quantitative methods such as laboratory experiments to qualitative ones such as informal interviews. The understanding of these background assumptions is a prerequisite for rigorous and relevant research (Keen 1991).

In the HCI community these assumptions have been discussed and reported by several authors and special workshops discussing the status of the field are organized. However, cognitive issues have been rarely discussed in detail (cf. Wærn 1989 and Preece 1994) and to our knowledge, there has been no comprehensive survey of the research methods used.

In this paper, we attempt to give a broad overview of the topics and methods used in the HCI research while focusing on cognitive aspects. To do this we have two approaches. First, we survey the existing literature while trying to find cognition related concepts. Second, we use these concepts to survey the existing literature from two major sources: ACM digital library and MIS Quarterly. Consequently, we present the extent to which different research methods are used, and bring up the categories related to cognition in the ACM and MISQ classification systems.

The structure of the paper is following. First we present an overview of the research area: the reference disciplines, research area and relevant theories behind the research. Next, we review the used research methods and survey the cognition related HCI literature, revealing the used research methods. Finally, the contributions are summarized.

Research field overview

Reference disciplines

There are several research disciplines and fields related to cognition, such as human-computer interaction (HCI), cognitive science, cognitive ergonomics, cognitive psychology, and artificial intelligence (AI). Generally, cognition refers to the processes concerned with acquiring, storing and using human knowledge, i.e. attention, perception, learning, memory, and problem solving (Wærn 1989).

Cognitive science is the study of intelligence and intelligent systems, with particular reference to intelligent behavior as computation (Simon & Kaplan, 1989). It has many reference disciplines common to HCI research, e.g. artificial intelligence, cognitive psychology, and linguistics (Simon 1995). HCI research relates also to the fields of computer science (CS) and education. In addition, Gerlach and Kuo (1991) mention ergonomics (used mainly in Europe; the American counter part being human factors), and social science. Table 1 presents how cognitive psychology resides between cognitive science and IS research.

Table 1: Reference disciplines of cognitive science, cognitive psychology, and IS

Cognitive science	**Cognitive psychology**	**Information Systems research (HCI aspect in parantheses)**
Artificial intelligence, cognitive psychology, and linguistics + a few other such as anthropology and epistemology	Part of cognitive science that has many common areas with cognitive science and IS research, especially with HCI	Computer science (application design and engineering of human interfaces), psychology (application of theories of cognitive processes and the empirical analysis of user behavior), sociology, anthropology (interactions between technology, work, and organization), and industrial design (interactive products)

Figure 1 illustrates the focus of this study, which is the sciences that provide HCI with knowledge about cognition. However, it must be noted that the figure only shows the most central disciplines dealing with cognitive aspects, and therefore e.g. psychology and the field of education are not explicitly shown.

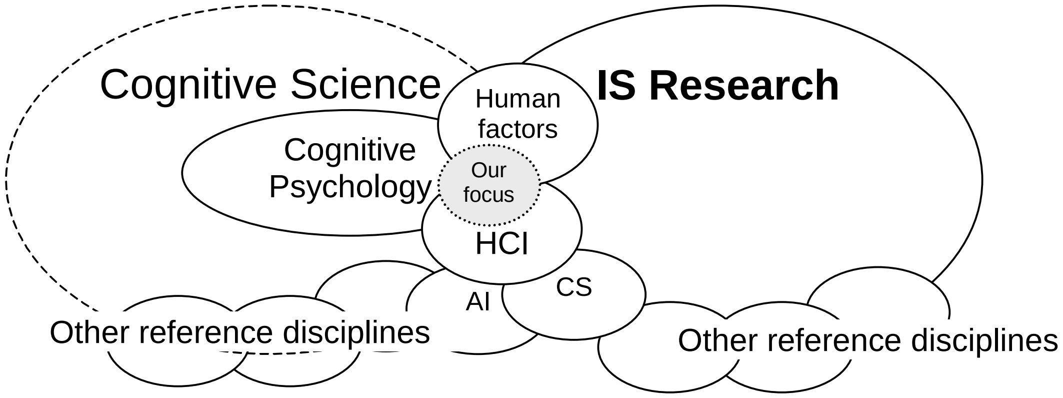

Figure 1: Focus of this study

Main objectives of HCI

The main goal of HCI is to provide usable and safe systems, as well as functional systems (Preece 1994). Broadly speaking, the concept of system includes software, hardware, and users of computer technology. To achieve the main goal, systems' safety, utility, effectiveness, efficiency, and usability could be developed or improved.

A key concept is *usability*, which is concerned with making systems easy to learn and use. Fundamentally, good usability implies understanding the factors that determine the users' effective operation on computer technology. Moreover, tools and techniques must be developed to help designers ensure that the system satisfies users' needs.

Currently, the field of HCI is broad ranging from technical software engineering aspects to human cognitive processes and organizational aspects. Table 2 presents the general objectives and methods of HCI and reference disciplines.

Table 2: Objectives and objects of interest of HCI in relation to cognitive psychology and cognitive science

	Cognitive science	**Cognitive psychology**	**HCI**
Objectives:	Aims to develop an understanding of how humans think and reason; how humans communicate with each other and with machines; and how humans adapt to their environments	Attemps to understand the basic mechanisms governing human thought (Anderson 1995) and tries to understand human behaviour by analyzing human mental processes in relation to stimulus from environment	Studies how people design, implement, and use interactive computer systems and how computers affect individuals, organizations, and society (Myers et al. 1996)
Objects of interest:	Knowledge representation, language, learning, thinking, and perception (Eysenck 1990)	Information processing, perception, learning, attention, memory	The use, design and implementation of efficient user interfaces (Myers 1994)

Research frameworks for HCI

Figure 2 shows the main topics that make the discipline of HCI (Preece 1994). Overall, it can be seen that HCI takes place within social and organizational context. It is important that tasks can be divided between human and computer so that the repetitive and routine tasks are allocated to computer while creative and non-routine tasks are performed by the user. Thus, cognitive aspects related to human information processing, language, communication and interaction must be considered. Similarly, it must be understood the range of possibilities that technology can provide while considering their suitability to humans.

The main technological issues involve input and output technologies, dialogue techniques, dialogue genre or style, computer graphics and dialogue architecture. Moreover, this knowledge serves as input to the design process. During the design process, tools and techniques are used to realize systems.

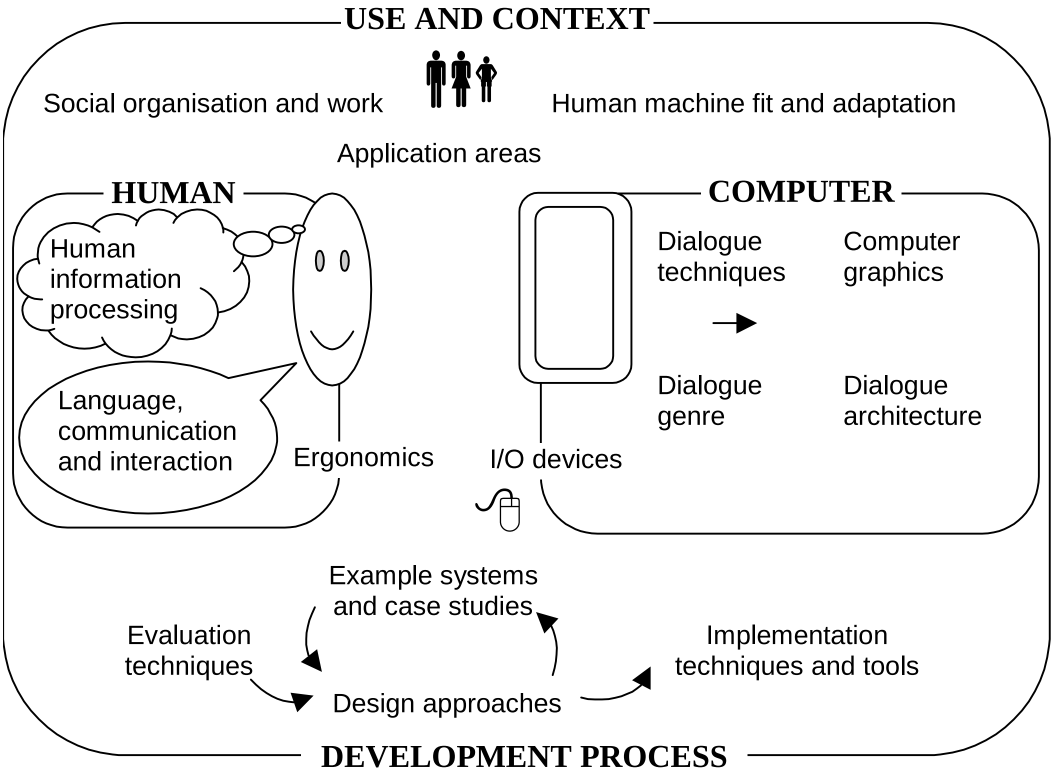

Figure 2: The Discipline of HCI (Preece 1994, originally in ACM SIGCHI, 1992).

Kuutti and Bannon (1993) proposed a three-level framework (Table 3) that helps to categorize and clarify the important underlying arguments in HCI. These levels are adopted from Iivari (1989) and they are organizational (O), conceptual (C) and technical (T). In regard to the interface issues, Kuutti and Bannon reduced the organizational level to consist of work processes or use situations. From the user's viewpoint in the use situation, the interface *is* the system (Norman 1986). Interface is not separated from functionality, because it is the way a user's work is supported by the system.

At the conceptual level, the interface must be mastered to be able to utilize the system or an application meaningfully (Kuutti and Bannon 1993). Therefore the role of the interface can vary in different applications, e.g. in the scientific visualization, the whole application belongs to the interface (Kuutti and Bannon 1991).

The interface at the technological level is "that part of the program that determines how the user and the computer communicate" (Newman and Sproull, 1979). In that respect, the interface and the application can be fully separated, whereas on the conceptual level they can overlap and on the work process level they are unified.

Table 3: Three-phase model of the enlargement of the HCI research domain (Kuutti and Bannon 1993)

Level	HCI research/design object area	HCI background theory

O	"Contextual interaction": situatedness, active actors, constructivity	"Enriched information processing psychology" or multidisciplinary approach: studying social contexts
C	Conceptual interaction	Cognitive psychology; studying mental models etc.
T	Physical/technical interaction	Psychophysiology; sensory, perceptional, movement coordination studies

Clearly, these three levels are also embedded in Figure 2 as part of social, individual and technical aspects. Looking at those three levels, the HCI research based on cognitive psychology belongs mainly to the conceptual level. The lowest level contains the physical aspects; especially in the early human factors studies. On that level human operations are more autonomous than on the conceptual and organizational level.

Recently the emphasis of HCI research has shifted more to the upper level focusing to the social contexts. The same trend can be seen in the field of education where the focus is now on the socio-cultural conception of learning. It emphasizes the social, cultural and historical origins of knowledge (Goldman et al 1999).

Areas of interest and their evolution

The interest in topics has shifted over the years, largely due to technological developments, but also to recognizing human needs (Myers et. al 1996). In the 70's and early 80's, psychologists became interested in the information processing aspects of computer system design. Such topics as menu names and depth versus breadth in menu design were popular areas of study.

The time when the computers became widely used, the usability with respect to single users was a concern. In the late 80's the trend has been towards very powerful multi-user workstations, improved communications, multimedia, multitasking-machines, and virtual reality. For example, by coupling a motion of the user's head to changes in the images presented on a head-mounted display, the illusion of being surrounded by a world of computer-generated images or a virtual environment is created. In addition, hand and other body-mounted sensors allow the user to interact with these images as if they were real objects located in surrounding space. Consequently group working, integration and interaction of media and the impact of such technologies in the workplace and in society has been studied (Preece 1994).

Moreover, one of the key problems is how to provide flexible interfaces that can be adapted to all users from novices to experts (Myers et. al 1996). Along the development of the UI research area new communities such as CSCW and Hypertext community have been established.

The most successful impacts of HCI research to practice

The major impact of user interface research can be seen in everyday applications in the form of direct manipulation, use of graphics, and mouse support. While some advancements such as mouse were based on theoretical work (Myers et. al 1996), theoretical foundations for some technological developments were given afterwards. For example, the theoretical basis for the concept of direct manipulation was given in the early nineties by Ben Shneiderman (1992). As can be seen from Figure 3, much of the research in HCI field has contributed to commercial products. A thorough list of advancements and their evolution is given by Myers (1998).

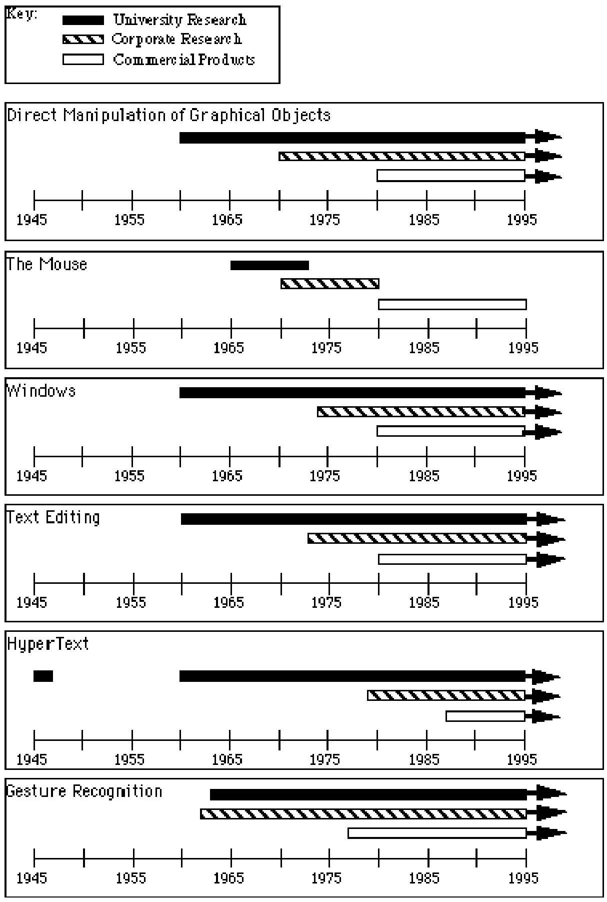

Figure 3: Approximate time lines showing where work was performed on some major technologies (Myers 1998)

While Myers does not indicate continuing research in the case of the mouse, it must be noted that technologies such as virtual reality (VR) require new input devices such as 3D mouse. Moreover, the community has not succeeded well in manifesting the developed usability guidelines to the industry, which is indicated by the varying quality of the WWW pages.

Some important concepts and theories

Some of the most well known cognition related concepts or theories used in HCI and cognitive psychology, and their implications for HCI are listed in Table 4 (see Preece 1994 for more details). Using the framework presented in Table 3, we classify them at three levels. When concepts and theories relate to more than one level, we used parentheses to indicate the secondary level.

Table 4: Some theories used in reference disciplines and their implication for HCI

Level	Concept / theory	Meaning	Implication for HCI
T	Perception and representation; ecological approach (Gibson 1979)	Perception is a direct process; picking-up information (not construction and elaboration)	Design of interface objects in terms of how they afford the actions that are intended to be performed on them

Level	Concept / theory	Meaning	Implication for HCI
T (C)	Perception and representation; constructivist approach (Gregory 1978), e.g. Gestalt laws	Information from the environment + prior knowledge and expectations	Organization of components displayed on screen; using metaphors
T (C)	Automatic and controlled cognitive processes (Shiffrin and Shneider 1977)	Some of the users' processes require use of memory and attention while some do not; automatic processes are difficult to unlearn	Consistent user interfaces
C (T)	Focused and divided attention; multitasking	Attention is relevant to the task being done, although sometimes we may try to do more than one thing at a time (divided attention)	Cognitive aids (Norman 1982): external representations (e.g. annotations, task lists) must be provided to manage tasks; inform about the status of an activity: what has been done and what should be done next (e.g. reminder prompts)
C (T)	Levels of processing theory (Craik and Lockhart, 1972)	Information can be processed in different levels: the deeper the level, the better the information can be remembered over time; meaningfulness is improved through familiarity of an item and its associated imagery	Increase meaningfulness of commands and icons
C	Recognition vs. recall; short-term memory (STM), long-term memory (LTM)	Recognition and recall in the terms of knowledge (Norman 1988): when we carry out everyday tasks we combine information in memory and information in the world	Graphical direct manipulation user interfaces, where objects and commands are displayed to the users
C	Knowledge representation; Schemas; Semantic networks (Collins & Loftus, 1975); Schemata (Schank & Abelson 1977); Mental models (Craik, 1943; Johnson-Laird 1983, 1988; Norman 1988)	In cognitive psychology: what are the different functions played by propositions, images and distributed representations in cognitive processing; are these distinct forms of representation?	To what extent does the form of representations used at the interface affect the way users think about solving problems; is it possible to develop interfaces that facilitate thinking and problem solving

Level	Concept / theory	Meaning	Implication for HCI
C (O)	Learning in context (Brown et al 1989); collaborative and situated learning (Winn 1993); socio-cultural theory	Learning is an active process and a collaborative process; therefore understanding individual cognitive and social processes are important	Providing help, considering different learning strategies and styles, recognizing and reducing errors, different interface styles for users in different levels of expertise, information visualisation, visual programming
O (C)	Social aspects; language/action approach (Winograd 1988), speech act theory (Austin 1962, Searle 1969)	Knowledge and language use in communication (application); comparing implications and principles derived from social and cognitive analyses of user behaviour	Screen (menu) design, design of computer-mediated conversations and group work
O (C, T)	Organisational aspects; scientific mgmt, sociotechnical approach, activity theory, ethnomethodology	Analysing the nature of work and society in relation to technology	Analysis of user interfaces (Bannon 1991) and CSCW systems (Kuutti 1993), design and implementation of CSCW systems

Looking at the levels in Table 3, we can see that the most theories belong to the middle, conceptual interaction level. The last three aspects – learning, social, and organizational aspects – can be located to the contextual interaction level.

Concerning the importance of theory development at different levels, the last three aspects have recently gained interest, such as in the area of distributed cognition. It conceptualizes cognitive activities as embodied and situated within the work context and analyzes how the different components of work environment are coordinated (Hutchins 1995).

Research methods

Galliers (1991) distinguishes two main approaches for IS research: traditional empirical (observations) and newer approach (interpretations). In addition, research methods have been widely categorized to quantitative and qualitative ones. In HCI research, variety of different methods and techniques are used.

There seems to be no clear understanding what methods belong to empirical research, which is sometimes considered more "scientific" approach as non-empirical research. Galliers (1991) mentions five modes for empirical approaches: theorem proof, laboratory experiment, field experiment, survey, and case study. Especially case study can also seen to belong to the interpretive methods, because it lacks control of variables. On the other hand, Cheon, Grover & Sabherwal (1993) list case study, survey, field study, field test, and laboratory experiment (including simulation and person-machine experimentation) as empirical methods. A most striking difference between these viewpoints is that Galliers mentions theorem proof while Cheon et al. mention field study. As a result, we combined those empirical approaches to include experimental studies (both in laboratories and in the field), observational studies (field and case studies), and surveys. A similar classification has been used when studying ergonomic issues and user behavior in HCI (e.g. Norman 1991, Rieman 1993, and Hill 1999).

Overall, problems with research methods have been reported. Results from experimental studies may have little effect on system usability, and observations in the workplace may yield primarily anecdotal data that do not support general conclusions (Rieman 1993). Therefore alternative approaches have been suggested, especially for assessing group settings. Contextual inquiry and design is an example of a method intended to quickly obtain a rich understanding of an activity and transfer that understanding to all design team members (Holtzblatt 1993). In addition, ethnographic observation, participatory design, and scenario-based design are also being streamlined (Schuler 1993). Table 5 summarizes the empirical methods and their strengths and weaknesses.

Table 5: Summary of main empirical methods used in HCI research

Method	**Observational studies**	**Surveys**	**Experimental studies**
Target	Users interacting with the system	User assesses factors related to HCI	Sample participants from the population of interest; one or several design features are selected for study
Examples	Verbal protocols (e.g. think aloud), contextual inquiry, ethnographic study / field observation, focus groups	Questionnaires, formal interviews, rating scales (e.g. Likert, semantic differential)	Laboratory and field experiments; controlled manipulation of variables and hypothesis testing
Collected	Time, productivity, and error data	Objective events (e.g. number of times a system crash) or subjective evaluations; demographic data; psychometric measures to assess intellectual skills, cognitive functions, and knowledge	One or several variables to measure; control all variables except those that are being tested
Data analysis	Descriptive or quantitative from e.g. video recordings	Interrelations among the variables, both quantitative and qualitative data	Statistical analysis normally from quantitative data
Strengths	Easiest to conduct; ability to generate hypotheses about design features (that can be studied in more controlled environments not open to multiple interpretation)	Reliability and validity of user responses; comparisons between different groups of subjects are possible	Ability to unambiguously locate an effect in a particular design factor; validity investigator establishes realistic conditions and assesses appropriate dependent measures; possibility to compare different groups
Weakness	Most unreliable and open to interpretation; little or no control over conditions	Introspective (assessments do not reflect the true values of the measures)	Experiment must be carefully monitored in order to detect flaws in the design and methodology; it is thus costly and often restrictive; difficult to generalize results

Review of the selected literature

To find out how the research on cognitive aspects in CS and IS has developed, we surveyed three digital libraries. During our search in The Collection of Computer Science Bibliographies (Achilles 1999) we found that the most references to cognitive aspects (of more than 930 000 references) were in the fields of HCI and AI. We limited our study in the cognitive aspects in HCI mainly because of the amount of references belonging to both fields. Of course, the distinction is not clear and articles selected for our study have references to both categories.

Two other valuable information resources for our study were HCIBIB (Perlman 1999), which has over 19 200 records (cf. Figure 4), and the ACM Digital Library, which includes over 36 000 titles (21 000 full-text articles; http://www.acm.org/dl/). In addition, The MIS Quarterly (MISQ) was searched by using a full-text search engine (http://www.cba.uga.edu/misq/articles.html).

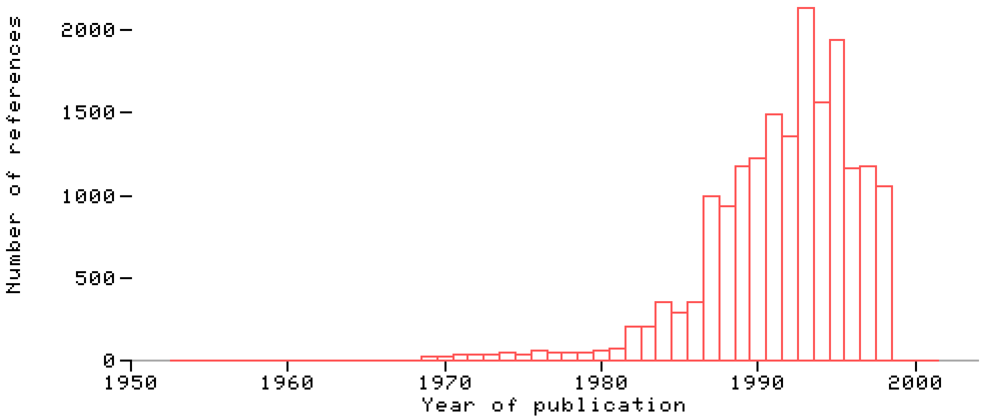

Figure 4: Distribution of HCI articles by publication dates

The notable increase of HCI articles in 1986 may partly be explained by the introduction of commercial products such as Apple Macintosh and Microsoft Windows™. A natural explanation for the steep fall from 1995 to 1996 is the delay in the bibliography maintenance.

Our research method

A set of concepts related to the cognitive aspects (see Table 4) was used to analyze IS articles. We included all ACM journals and proceedings and MIS Quarterly for two reasons. First, they are established IS journals and second, they both provide a classification framework. In addition, search facilities are available which however differ in their capability.

The ACM classification scheme involves three concepts: general terms, implicit subject descriptors, and the four-level tree (containing three numbered levels and a fourth unnumbered level). MISQ uses a similar classification (MISQ 1998), but it can't be directly related to ACM classification system. Therefore, we imported both the classification systems into a spreadsheet and added the missing level codes and combined the classification systems by using a macro program.

Surprisingly, MISQ articles cannot be directly searched by using MISQ Keyword Classification Scheme. In addition, the keywords used in cognitive science are not heavily used in IS research, so we used a full-text search in both search engines. The articles were briefly analyzed and the most relevant categories of ACM and MISQ were combined for further exploration.

Category analysis

We found that most of the ACM journals and conference proceedings (relating to the cognitive aspects) belong to class *H.1: models and principles, H.5: information interfaces and presentation* (e.g., HCI), and *I.2: artificial intelligence*. In these main categories two relevant subcategories we distinguished, namely *H.1.2 (user/machine systems, human factors and human information processing)* and *H.5.2 (e.g. user interfaces)*. Cognition related articles were found also in the other categories, but we excluded them because most of them were included in H.1.2 and H.5.2. Moreover, our quick review showed that other relevant categories (see appendix) contained mostly technical and other non-cognition-related articles.

The corresponding categories in MISQ classification belong to two distinct main categories, *AA: behavioral science* (in the reference disciplines) and *HC: Components of IS*. The most appropriate subcategories in behavioral science were *AA02: Human factors, AA03: Individual differences, and AA04: Human information processing.* HCI related subcategories were *HC01: Interface,* and especially its subcategory *HC0101: User/machine dialog*. It should be noted, however, that a corresponding MISQ category for cognitive science (AC07) was not found in ACM classification (see Table 6) and cognitive psychology is not mentioned at all.

Table 6: The common categories of ACM and MISQ related to cognition (see Appendix)

Category	ACM	MISQ
Human factors	H.1.2	AA02
Cognitive style	(H.5.2)	AA0301
Human information processing	H.1.2	AA04
Cognitive science		AC07
Ergonomics	H.5.2, I.3.6	AN
Interface design	H.5.2	FB0403
Human/computer interaction	H.5	HC0101
Graphical user interface	H.5.2	HD0108

Summary of findings

A total of 802 ACM articles in journals and conference proceedings was found to belong in both H.1.2 and H.5.2. All of them were published during the 90's. Only 20 MISQ articles were found to contain the keywords mentioned in the Table 6 of which 13 dealt with cognitive aspects. Seven of them were published during the 90's. A more in-depth search revealed that there were 265 ACM articles related to the cognitive aspects of which 44 were in journals.

The most references to cognitive aspects were found in ACM conference proceedings, approximately 90 % when we conducted 5 different searches in the ACM digital library. Most of the journal articles appeared in *ACM Transactions on Computer-Human Interaction* and *Interactions.* Most of the conference papers were published in

ACM CHI conference proceedings.

The next step was to select articles for inspection: we picked all the articles (121) that had an abstract in the bibliography and summarized the used methods (Table 7). However, because every fourth abstract did not explicitly reveal the used methods, we inspected the actual articles. Table 7 shows that an empirical method was used in nearly half of the articles.

Table 7: Distribution of research methods in selected ACM and MISQ articles

Method	**Articles**	**%**
Interviews	3	6
Surveys	5	9
Laboratory and field experiments	35	65
Field studies	6	11
Case studies	5	9
Empirical	54	45
Non-empirical	67	55
Total	**121**	

The most used empirical method is experiment, which can be clearly seen in Figure 5. However, there were few experiments where also observations were used as a secondary method; thus they were not included in the observational methods. Moreover, there were three interviews, which were classified surveys. We also noted that although laboratory and field experiments were not separated in our study, a laboratory setting could be explicitly found in many articles.

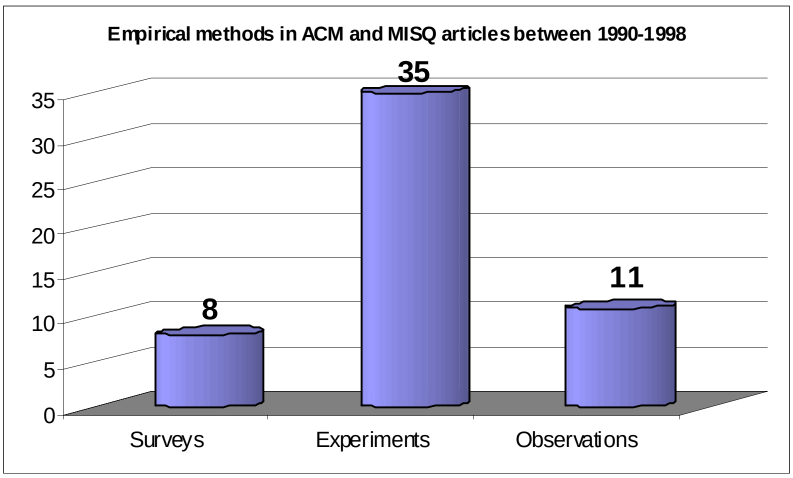

Figure 5: Empirical methods in ACM and MISQ articles between 1990-1998

Figure 6 suggest that the number of cognition-related articles in journals is growing though, the low number of articles diminishes the possibility for strong arguments.

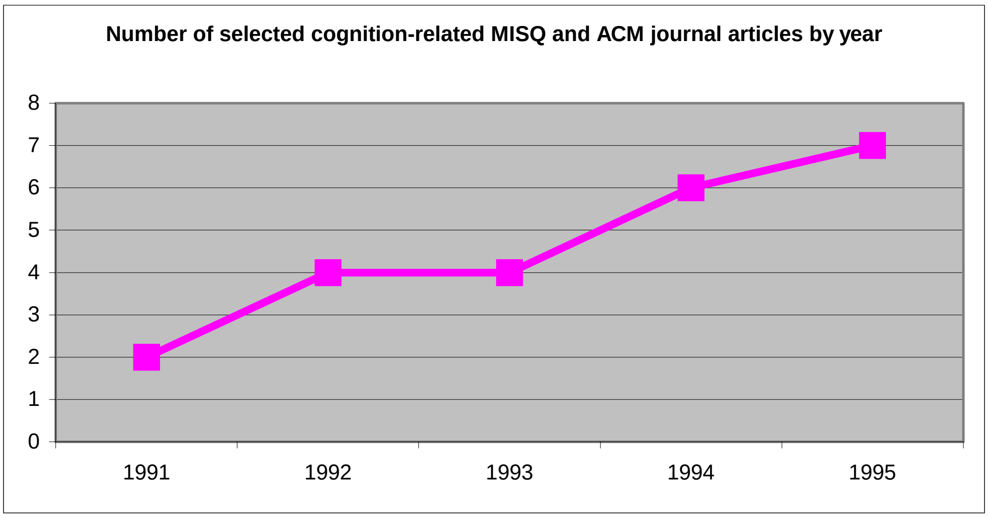

Figure 6: Number of selected cognition-related MISQ and ACM journal articles

Conclusions

In this paper, we have addressed two important aspects of the HCI discipline: the structure of the field and the used research methods. The first aspect was tackled by studying literature, which revealed that the field has several cognition-related reference disciplines, and that it benefits from fundamental theories from cognitive psychology. Moreover, we reviewed the general research topics and showed how these theories relate to organizational, conceptual and technical levels in the framework presented by Kuutti and Bannon (1993).

We also conducted a literature survey of cognition related articles with focus on the used research methods. The results show that empirical (45%) and non-empirical (55%) methods are used almost evenly. Moreover, we found that experimentation is the most widely used empirical method (65%). Furthermore, we studied the structure of two major IS literature classification systems (ACM and MISQ) and showed the categories related to cognition.

The literature analysis may have suffered from some limitations. One possible problem was a biased selection of the articles. The survey was dependent on the content of the used digital libraries, thus not all articles relevant to our criteria could be used in the analysis. Moreover, we can argue over the concepts that can be used as search terms while searching cognition related articles. Neither we can be sure that all relevant articles actually use concepts related to cognition. Despite, we see that this study is a good starting point for further research.

Acknowledgements

We want to thank Minna Koskinen for her constructive comments and critique. We are also grateful to Professor Kalle Lyytinen, Anja Mursu, and Nazmun Nahar for their comments on the earlier version of the paper.

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Appendix

ACM classification levels in IS main category related to HCI

The following two categories were the most relevant to our studies:

H.1.2 User/Machine Systems; Human factors; Human information processing; and Software psychology.

H.5.2 User Interfaces (references also in D.2.2, H.1.2, I.3.6); Auditory (non-speech) feedback; Benchmarking; Ergonomics; Evaluation/methodology; Graphical user interfaces (GUI); Haptic I/O; Input devices and strategies (e.g., mouse, touchscreen); Interaction styles (e.g., commands, menus, forms, direct manipulation); Natural language; Prototyping; Screen design (e.g., text, graphics, color); Standardisation; Style guides; Theory and methods; Training, help, and documentation; User-centered design; User interface management systems (UIMS); Voice I/O; and Windowing systems.

In addition, the following categories were briefly examined:

D.2.2 Software Engineering; e.g. Design Tools and Techniques; User interfaces

H.5.1 Multimedia Information Systems; Animations; Artificial, augmented, and virtual realities (revised); Audio input/output; Evaluation/methodology; Hypertext navigation and maps; and Video.

H.5.3 Group and organization interfaces including CSCW and Web-based interaction.

H.5.4 Hypertext/Hypermedia; Architectures; Navigation; Theory; and User issues

I.2 Computing Methodologies, Artificial Intelligence

I.3.6 Methodology and Techniques; Device independence; Ergonomics; Graphics data structures and data types; Interaction techniques; Languages; and Standards

I.7.2 Computing Methodologies, Document and text processing; Document Preparation, Hypertext/hypermedia.

K.3.1 Computing Milieux, Computers and education; Computer Uses in Education, Computer-assisted instruction (CAI).

MISQ classification levels in IS related to HCI

AA Behavioral Science (used for organizational behavior)

AA02 Human factors (used for behavioral factors)

AA03 Individual differences (used for individual characteristics); AA0301 Cognitive style; AA0302 Locus of control; AA0303 Personality

AA04 Human information processing; AA0401 Information recall

HC Components of IS

HC01 Interface (used for User interface)
HC0101 User/machine dialog (used for Human/computer interaction, Person/machine interaction); HC0102 Command language; HC0103 Database views; HC0104 Direct manipulation