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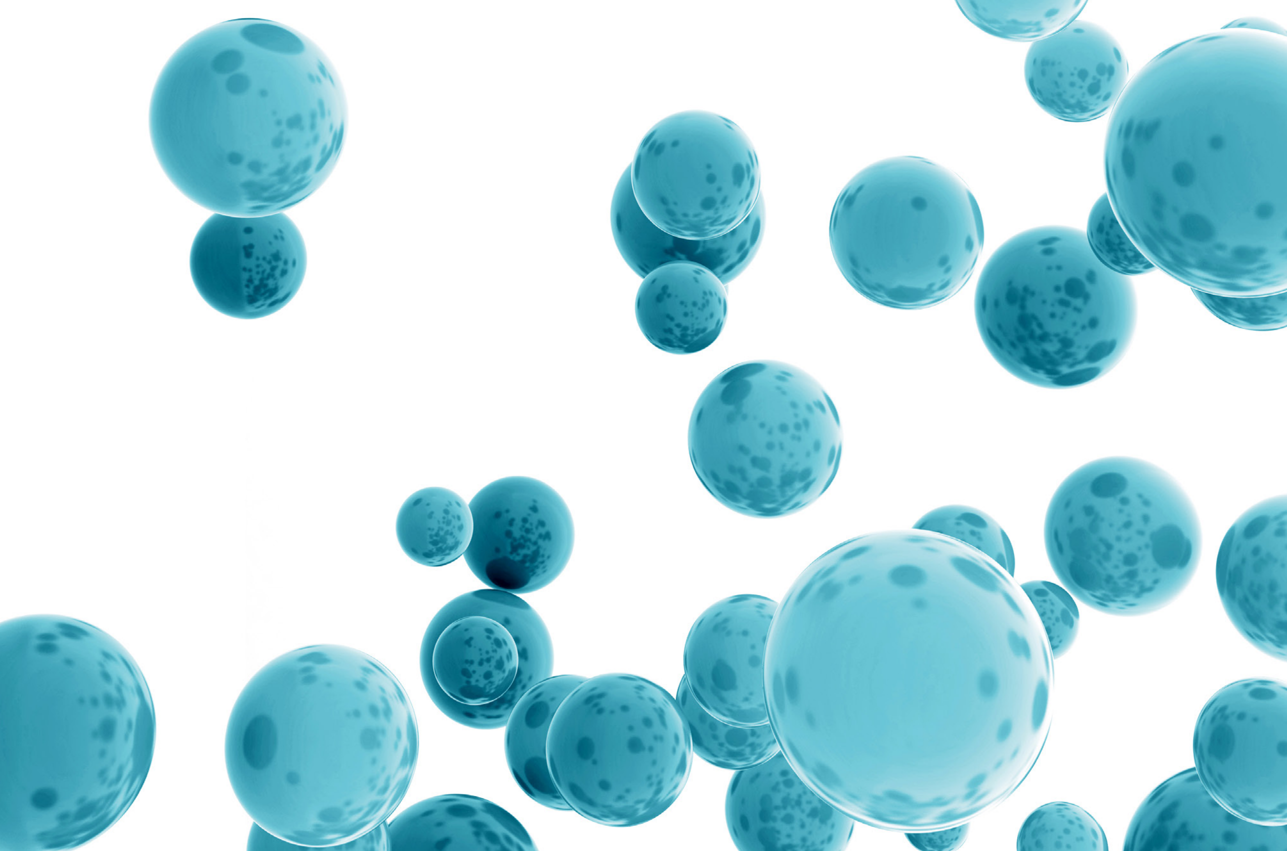
Information Searching in Authentic Work Tasks

A field study on the effects of task type and complexity



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ACADEMIC DISSERTATION
To be presented, with the permission of
the Board of the School of Information Sciences
of the University of Tampere,
for public discussion in the auditorium Pinni B 1096,
Kanslerinrinne 1, Tampere, on 14 January 2017, at 12 o'clock.

UNIVERSITY OF TAMPERE

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Jos koet syyttä suotta puuttuvasi listalta, otathan minuun yhteyttä asian hyvittämiseksi!

If you feel that you too should have been on this list, please contact me for recognition!

Tiivistelmä

Tässä tutkimuksessa selvitettiin, miten tietotyöntekijät hakevat tietoa päivittäisiin työtehtäviinsä. Tiedonhakua tutkitaan tyypillisemmin testiympäristöissä tarjoamalla tutkittaville keinotekoisia työ- tai hakutehtäviä suoritettaviksi, mutta tämä tutkimus pyrki näkemään tiedonhaun laajemmassa yhteydessään.

Tutkimus koostuu kahdesta aineistosta, jotka on kerätty seuraamalla tutkittavien työtä kentällä eli tutkittavien omilla työpaikoilla. Tutkimukseen osallistui yhteensä 28 henkilöä 7 eri organisaatiosta. He suorittivat aineistonkeruun aikana (v. 2011 ja 2013-2014) 345 jatkoanalyysiin päätynyttä työtehtävää. Aineisto koostuu kyselyvastauksista, tutkijan paikan päällä keräämästä havainnointimateriaalista, haastatteluista, lokeista ja ruudunkaappausvideoista. Tutkimuksessa analysoidaan työtehtävän monimutkaisuuden ja tyypin yhteyttä tiedonlähteisiin, hakutehtäviin ja tiedontarpeisiin. Empiirinen tutkimus osoitti, että työtehtävien suorittamisessa käytetään paljon erilaisia lähteitä ja laajemmin tietoresursseja. Ne voidaan jakaa seuraaviin luokkiin: Web (sisältäen hakukoneet), organisaation tietojärjestelmät, henkilölähteet/viestintävälineet (sisältäen sähköpostin), paikalliset tietoresurssit omalla tietokoneella ja muut, tyypillisesti paperiset tietolähteet (esimerkiksi tulosteet ja muistiinpanot).

Tutkimus osoitti, että työtehtävän monimutkaisuus vaikuttaa tiedonlähteiden valintaan ja tarvittuihin tietotyyppeihin. Tietotyypit ja tiedonlähteet ovat myös yhteydessä toisiinsa. Työtehtävän tyyppi ja monimutkaisuus ovat yhteydessä siihen millaista tiedonhaku työtehtävissä on ja paljonko sitä esiintyy. Kun työtehtävän monimutkaisuus kasvaa, kasvaa hakutehtävien ja niihin sisältyvien kyselyiden lukumäärä. Monimutkaisuuden yhteys tiedontarpeisiin taas riippui tässä tutkimuksessa aineistosta. Kuitenkin vaikuttaa siltä, että monimutkaisimmat työtehtävät sisältävät monimutkaisempia tiedontarpeita ja hakuprosesseja kuin muut työtehtävät. Samalla tavoin intellektuaalisten tehtävien luokkaan kuuluvat työtehtävät eroavat muista tehtävätyypeistä: ne sisältävät enemmän hakutehtäviä ja kyselyitä kuin muuntyyppiset työtehtävät, ja tiedontarpeet ja hakuprosessit ovat monimutkaisempia.

Tutkimus rajoittui suhteellisen pieneen aineistoon, jonka pääasiallisesti keräsi ja analysoi kirjoittaja yksin. Tulevaisuudessa tiedonhaun ja tiedonhankinnan tutkimus

hyötyisi vastaavista tutkimuksista, joissa olisi mahdollista kerätä suurempi aineisto ja analysoida sitä tutkimusryhmän voimin. Myös kontrolloidummissa käyttäjätutkimuksissa voitaisiin hyödyntää ajatusta siitä, että todelliset työympäristöt ovat monilla tavoin monimutkaisia. Esimerkiksi simuloituja työtehtäviä tulisi kehittää ongelmanratkaisukeskeisempään suuntaan nykyisen hakukeskeisyyden sijaan.

Aiemmasta tutkimuksesta poiketen väitöskirjassa yhdistettiin eksplisiittisesti tiedonhankinta- ja tiedonhakututkimuksen lähestymistapoja sekä laadullisia ja määrällisiä menetelmiä. Tällä tavoin analysoitiin kentällä kerättyä aineistoa, jossa työtehtävät ja tiedonhaku ovat kiinteästi yhteydessä toisiinsa.

Todellisten käyttötilanteiden ja -tarpeiden tulisi olla perusta tiedonhakujärjestelmien tutkimukselle ja kehittämiselle. Tämä lähtökohta sai vahvistusta tässä tutkimuksessa, kun osoittautui, että tiedonhaku aidoissa työtehtävissä ei täysin vastannut aiemman kirjallisuuden luomaa kuvaa tiedonhausta.

Abstract

The present thesis aims at contributing to the understanding of information searching as real-life phenomenon as opposed to information retrieval studied in laboratory settings. The thesis also provides methodological knowledge about how to collect data in the field and how to analyse it.

The data include two independent data sets. They were collected in authentic working situations of 28 participants in seven organisations in 2011 and 2013-2014, and include direct observation, questionnaire responses, interviews, transaction logs and a screen capture video. The data include 345 work tasks. The analysed variables are work task complexity and type, information resources, search tasks and information needs.

The study showed that work task complexity affects the selection of information resources. In their work, people use various information resources that form broad categories of the Web (including public search engines), organisational information systems, communication resources (including email), local PC resources and other, typically paper-based resources. Information needs and information resources are connected. Work task types and complexity affect the quality and quantity of query-based information searching. Growing work task complexity indicates an increasing number of search tasks and queries. The findings concerning work task complexity and information needs vary between the two data sets. However, it seems that the most complex work tasks include more complex information needs and search processes than other tasks. Similarly to complex work tasks, also intellectual work tasks differ from other task types: they include more search tasks with more queries, and information needs and search processes are more complex.

The limitations of the study include the rather small data set collected and analysed by mainly one researcher. Future research would greatly benefit from collecting a similar but larger data set and analysing it in a research group including various areas of expertise.

The study suggests that current research into interactive information retrieval could have a wider scope: the complexity of real working environments should be taken into account in experiments as well. For example, simulated work task

situations could be developed towards a problem solving centric approach instead of the prevalent search-centric approach.

The study differed from earlier studies in that it explicitly combined ideas of both information seeking and information retrieval research as well as qualitative and quantitative approaches. This combination was used in analysing authentic field data that linked information searching to work tasks.

The real-life needs and uses should be kept as the point of departure of information retrieval system development and related research. This starting point was confirmed in the present study, as the findings suggested that real-life searching does not totally respond to the picture given by earlier literature.

Table of contents

Original publications

This dissertation consists of a summary and the following original research publications. The publications are referred to as papers I-VI in the summary.

I Saastamoinen, M., Kumpulainen, S., & Järvelin, K. (2012). Task complexity and information searching in administrative tasks revisited. Proceedings of the 4th Information Interaction in Context Symposium, Nijmegen, the Netherlands, pp. 204-213.

II Saastamoinen, M., Kumpulainen, S., Vakkari, P., & Järvelin, K. (2013). Task complexity affects information use: a questionnaire study in city administration. Information Research, 18(4).

III Saastamoinen, M. & Kumpulainen, S. (2014). Expected and materialised information source use by municipal officials: intertwining with task complexity. Information Research, 19(4).

IV Saastamoinen, M. & Järvelin, K. (2016). Search task features in work tasks of varying types and complexity. Journal of the Association for Information Science and Technology. [In press.]

V Saastamoinen, M. & Järvelin, K. (2016). Queries in authentic work tasks: the effects of task type and complexity. Journal of Documentation, 72(6), 1114 - 1133.

VI Saastamoinen, M. & Järvelin, K. Work task types, complexity and usage-time of information resources: a field study of relationships. [Under review for Journal of Information Science.]

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The authors' shared research contributions for the original research papers are as follows:

I All authors contributed to the overall design of the study. Kumpulainen also collected a third of the data in the field. Kumpulainen and Järvelin contributed to the revisions of the paper. Järvelin supervised all phases of the study. Everything else is done by the first author.

II The paper shares the data set with paper I. Kumpulainen, Vakkari and Järvelin contributed to the revisions of the paper. Järvelin supervised all phases of the study. Everything else is done by the first author.

III The paper shares the data set with paper I. Kumpulainen contributed to the revisions of the paper. Everything else is done by the first author.

IV-VI Both authors contributed to the overall design of the study. Järvelin contributed to the revisions of the papers and supervised all phases of the study. Everything else is done by the first author.

1 Introduction

The present thesis is intended to shed light on people's information searching in real-life work context, here called *task-based information searching:* the approach combining ideas of information retrieval (IR) and information seeking research in the context of real-life tasks (*cf.* Vakkari, 2003, p. 413). This is an explorative empirical study, meaning that the idea is to understand the phenomenon by analysing real-life data, rather than to test strict hypotheses, as could be done in experiments. However, the explorative approach does not exclude having a focus (Blandford & Attfield, 2010). The point of departure is that work-related searching is just that; *related* to the work, the work tasks, that give rise to the searching in the first place. I study professionals of various domains (city administration, business, university) and consider work task features as the key factors affecting on how information is searched for in work task performance. The research questions are answered with a versatile data set including field notes, logs, questionnaires and interviews.

Borlund (2000) and Kelly (2004) and their later work have had an important role in the field of information searching. Both aim at finding ways to bridge the gap between traditional, so called laboratory IR studies and the real life happening outside the laboratories. This is definitely the idea behind the present thesis as well.

The approach taken stems from the information seeking models of Leckie, Pettigrew and Sylvain (1996) and Byström and Järvelin (1995). They both discuss the information seeking processes of professionals, and work task is seen as the key factor affecting information needs and information sources. The large perspective of these two classical models is here further refined by focusing on IR actions in addition to more traditional variables typically used in information seeking research.

1.1 Background and scope

Figure 1 shows the scope of task-based information searching approach and the present study. The figure is closely related to Wilson's (1999) and Ingwersen and

Järvelin's (2005) nested models. The difference is that I have included only the concepts that are most important for the present study. Thus, Figure 1 is not "yet another information seeking or contextual model" but shows the present study's objects of interest in relation to each other following literature and the approach of the present study. Similarly, not all possible connections are presented.

Information retrieval is shown as the most specific object of interest. IR actions, such as forming queries, reading snippets and following links, can also be seen as forming *search tasks*. A still wider context that search tasks belong to is that of *information seeking*. It includes IR but takes into account other ways of finding information, as well. Information seeking is performed using various information sources, including IR systems. IR, search tasks and information seeking are part of larger tasks, that are here called *work tasks*. Work tasks have various features (for example complexity) and they are performed using information resources, such as information systems, and various types of information. Work task performance may create information needs, potentially leading to information seeking.

Task-based approach has also been critisised by, for example Talja and Nyce (2015) who claim that tasks should be seen as a part of larger *context*. The present study acknowledges that wider contexts exist (*e.g.* organisation) but analysing them is out of the scope of the present thesis. Work tasks discussed here are part of *information-intensive* or *knowledge work* which means that information plays a key role in work task performance: information acts as both input and output of work.

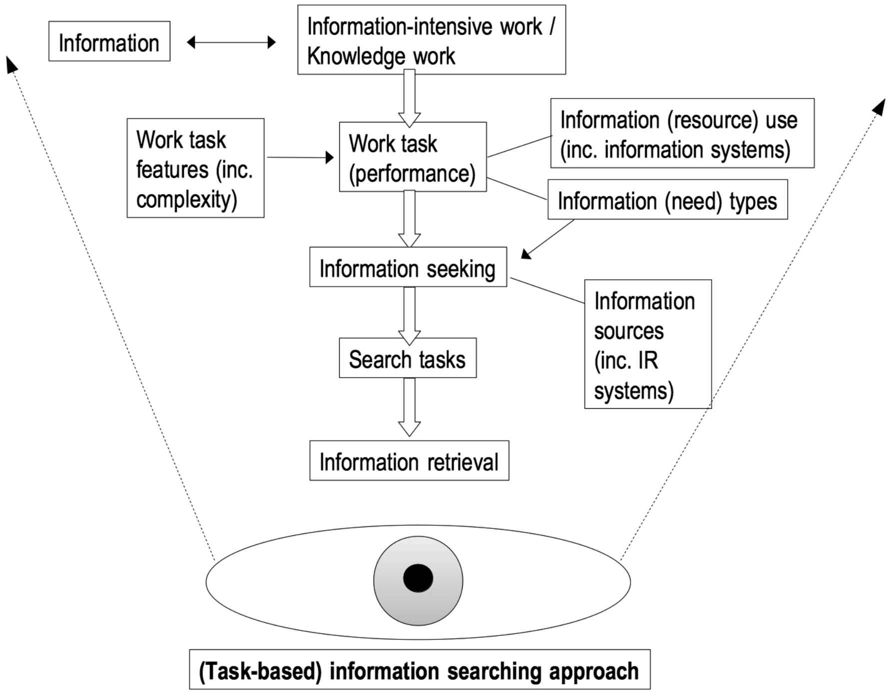

Figure 1. The conceptual framework of the study: dotted arrows denote the scope of the approach; two-way arrow denotes the two-way role of information as both input and output of information-intensive work; block arrows point to nested concepts; thin arrows denote effects; solid lines denote components of the left-side concepts.

Next, I discuss the thesis' key concepts presented in Figure 1. The most relevant ones for the present thesis are more thoroughly discussed in the next section.

Knowledge work is widespread in today's society. Knowledge work, as opposed to more "traditional" work, requires formal education, innovativeness and flexibility on behalf of its performers who work with information and create new knowledge rather than work with tangible materials to produce goods (Pyöriä, 2005, p. 124). Thus it is obvious that the availability of information is essential to successfully perform such work tasks. According to Alvesson (2004), it is common for organisations to have special units for knowledge work even if the majority of their employees were working with routine information processing or other types of tasks. Knowledge work tasks are inherently non-routine according to Pyöriä (2005). Organisations whose greatest asset is human capital (as opposed to, for example, the material one) and whose main field is to produce knowledge or innovations, are referred to as knowledge organisations (Amar, 2002).

Other terms for the same or similar phenomena to knowledge work and knowledge organisations are knowledge-intensive work (Cross & Cummings, 2004) and knowledge-intensive firms (Alvesson, 2004), or **information-intensive work** (Glazer, 1991; Hansen & Järvelin, 2005; Byström & Hansen, 2005) often as a wider counterpart to knowledge work. Glazer (1991) states that organisations can be placed on a continuum according to their information-intensiveness. Information-intensiveness means that information is an important asset adding value and being a part of the products - or information may be the product itself (Glazer, 1991, p. 6).

Typically, the concept of information-intensive work does not exclude routine tasks (*cf.* knowledge work). In the present study, also routine tasks dealing with information are included, and the terms knowledge work and information-intensive work are used interchangeably. For Li and Belkin (2008) however, information-intensive tasks mean actually tasks where information searching is in a central role. In my use, information-intensiveness or knowledge work refers to the extensive role of information in the work tasks (creating, using, searching, disseminating…) rather than to an expectation of extensive searching. Information search tasks or information seeking tasks may be minor or major components of work tasks. This separation is beneficial even considering my research questions: analysing the connections between (information-intensive) work tasks and the number of search tasks, for instance.

Work is formed of separable **work tasks**. Byström and Hansen (2005) differentiate between work tasks as concrete steps, that is, task performance processes, and work task assignments which are the labels or descriptions of work duties typically manifesting as several processes. The present thesis analyses work tasks as concrete processes that are *ad hoc* labelled by the participants.

Work tasks sometimes include smaller subtasks, **search tasks**. As well as work tasks, also search tasks are here understood as concrete processes, rather than as some predefined subtasks of work tasks or duties. A prevailing theme throughout the thesis work has been that most search tasks are born *ex tempore* in diverse work situations instead of being objective search tasks that would be included in the work task assignment itself.

Information searching is basically performed in order to find **information** and to gain knowledge. Information searching deals with *information-as-thing*. Information-as-thing is something detectable, such as an object or data, and it has the potential of being informative which actually depends on the situation (Buckland, 1991). According to Ingwersen and Järvelin's (2005, p. 385-386) view, information objects carry potential information because the term *information* entails that it is both intellectually produced and changes the recipient's knowledge. Thus, it is actually the potential information for which people are searching. Also Allen (1996) argues that information is essentially a process of being informed. However, this definition seems to exclude (still) undiscovered information-as-things that are important especially in IR research (*cf.* Ingwersen & Järvelin, 2005). The actual process of being informed may also be called information use (Kari, 2010).

In the present thesis, the term information does not carry a meaning of being true or fresh (important aspects for the searcher, though), for example, because anything detectable can act as information in a favourable situation. Even if the "information" found was in a wrong language or false, the process of *information searching* still existed, successful or not (sometimes no information is found).

I call *potential information* simply *information*. In my research, two definitions of information have proved most important in terms of information searching: first, information as an idea, and second, information as stored somewhere to be found. On the one hand, when the searcher starts searching, she has an idea (no matter how vague) of what she is searching for. I like to think that what she is searching for defines information though it exists only as an idea in the searcher's mind; nobody can say whether there exists a real piece of information that fits this idea, not to mention that it would affect the searcher's knowledge. If the searchers already had the information, they probably would not search in the first place (Allen, 1996). On the other hand, I also like to think that, for example in a Web search engine's database, there exists a great deal of information regardless of whether they are ever found by searchers or whether they are able to change someone's knowledge. That is, analysing information searching or performing it is sensible only if there is something to be found. Of course this could also be called potential information or data. Research of information searching analyses how these two definitions of information meet, and as explained above, some researchers call this encounter *information*.

Information needs trigger information searching (see also Section 2.2). In earlier research, they have been described for example as gaps in the knowledge (Dervin, 1983): people have an understanding that they do not know something and they have to decide what to do. An option is to perform **information seeking** which is a person's effort to find information by using **information sources** (*e.g.* Ingwersen & Järvelin, 2005).

Information retrieval is a special case of information seeking and a field of research of its own. The difference between information seeking and IR is that IR is information seeking conducted using an IR system (Wilson, 1999; Ingwersen & Järvelin, 2005). Information seeking and IR originate from two different schools of thought. Traditional information seeking research is social science that explores the ways people use information sources, channels and services. Traditional IR studies concentrate on optimising the performance and related aspects of IR systems in question. (Vakkari, 1999; Ingwersen & Järvelin, 2005; Blandford & Attfield, 2010.)

Information searching is a term related to information seeking and IR, and it is used in varying ways in literature. Sometimes it refers to information seeking as a whole (using any kinds of information sources), sometimes to the actions of information retrieval (searching by querying; *cf.* search task). I use the term information searching to refer to the viewpoint applied in the present thesis: using IR systems and formulating queries is of special interest for the study, but also the wider context of information seeking, typically present in authentic work task performance, has been analysed (see more discussion in Section 2.1). Following this approach, I also prefer using information searching as a verb whenever the use context is suitable.

Information use is what comes after the information is found. It may refer to several things from the change in a person's knowledge structure to producing new information. Kari (2010) has analysed the concept of information use. In the present thesis, information use is not analysed *per se*. However, being an important part of real-life task performance, it is present in the data. For example, gaining new knowledge is visible in how participants revise their queries; and reading, writing and searching naturally intertwine in task performance, thus being hard to separate based on simple log data.

Figure 2 presents an ordered selection of empirical approaches to studying the phenomena presented above in Figure 1. The approaches are presented as a continuum of growing realism from left to right. The continuum is similar to the one Kelly (2009) presented. However, Kelly (2009) emphasised the left side whereas I emphasise the right side. Robertson (2008) portrays quite aptly the rather everlasting problematics and trade-off between strict, artificial experiments that foster scientific accuracy, and field studies providing valid information that may not be that useful in scientific sense. However, I still stand on the field study side of the argument. Field studies are needed to retain a real-life touch within research, otherwise there is a risk that research is conducted following established methods but the findings do not have equivalent in real-life contexts. Nonetheless, practical issues of system design and experimenting demand the existence of the other side of the continuum, as well. People do a lot of things during their work and leisure time, and only occasionally search for information. In order to catch enough data for accurately analysing specific types of searching in the flow of people's every day lives would require huge amounts of data.

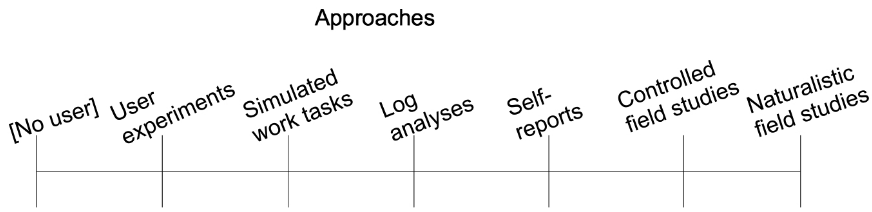

Figure 2. Approaches to studying task-based information searching.

In the left-most end of Figure 2, **no user** in brackets stands for studies of traditional IR where human participants are not needed, or the participants are even simulated (Keskustalo, 2010). Brackets stand for the fact that these studies belong to this continuum only technically, as a logical step left from user experiments, but they typically do not apply the idea of task-based information searching. Studies discussing the development or evaluation of IR systems are out of the scope of the present thesis.

User experiments are conducted in laboratory-like, controlled environment. Users can be actually needed only as an extension, a ”random variable” of the studied IR system. They form queries and/or perform relevance assessments according to the instructions given. Studies exploiting **simulated work tasks** (Borlund, 2000) aim to study user behaviour rather than mere performance of an information system. However, the situation itself is artificial, similar to user experiments. This is why the continuum presents log analyses as more realistic than simulated work tasks.

Log analyses are typically studies with large quantities of server-side log data, though also studies using client-side logs exist. Server-side log data are collected from real searchers in the real world, but the logs lack explicit contextual grounding: who searched for what and why, what kind of search or work task was involved *etc*. **Self-reports** (search diaries, interviews, questionnaires) include the contextual information missing from a basic server-side log, but on the other hand, alone they do not expose the real search actions, only narratives out of them. There are several reasons why the narratives may not be quite accurate, from the function of the human memory to the human need to rationalise behaviour (Kumpulainen *et al.,* 2009, p. 51).

Controlled field studies are conducted in a laboratory-like situation, but the tasks performed are authentic instead of assigned ones. The concept of control is of course somewhat looser than in case of user experiments. Here it refers to, for example, that the participants are in a space that is reserved for the research, they use the equipment provided during a limited time window, and their actions are recorded. The reverse is also technically possible: the participants perform assigned tasks in their natural working environments. The present thesis belongs to **naturalistic field studies** which do not control the actions of participants in any way but the work is followed as it is. The only difference to a truly authentic situation is the participation to the study, with the consequence that a logging software is running or an observer sitting in the participants' office (*cf.* Kumpulainen & Järvelin, 2010). The participants may do any work tasks with any resources as long as they need to, and take normal breaks.

Figure 2 is only one view of the order of the approaches. Especially the mutual order of simulated work tasks, log analyses and self-reports depends on which study features are perceived as increasing realism. As stated above, in simulated situations, the search actions are authentic but tasks are not; in log studies, the search actions are authentic and they are based on authentic tasks that, however, usually are not known; and self-reports are, in principle, authentic in both tasks and actions but they cannot be verified.

In order to achieve the goals of the present study, it was necessary to apply the naturalistic field study approach. It allows us to study information searching from the viewpoint of the tasks and their performers. User studies or server-side logging methods presented above do not typically analyse the use of multiple information resources that are consulted when satisfying authentic information needs. We are also able to analyse the variation of real-life work tasks. Typically in earlier research, tasks are not known, or their variance is artificially created for research purposes, or only one type of real-life work tasks is studied.

1.2 Research questions and objective

Results from six empirical research papers and two data sets, A and B, are used to answer the research questions of the thesis. The main independent variables are perceived work task complexity and work task type. Work task complexity is an aggregate variable formed of the estimates given by the participants, and it is applied in all papers. Work task types are a data-driven categorisation based on Data Set B and applied in papers IV-VI. The research questions in the present thesis are as follows:

1. **What characterises real-life work tasks and their performance from the perspective of information searching?**
   Work task features and information resource types are analysed, as well as the number of resources, search tasks and problems in task performance between diverse work tasks. (Papers I, III, IV, V, VI.)
2. **What information is needed to perform work tasks, and what are the effects of task type and complexity on the needs?**
   The analysis concerns the types of information needed and used, and how work task features affect them. (Papers I, II, IV.)
3. **How are information resources used to perform work tasks, and what are the effects of task type and complexity on the use?**
   This question considers the use of various information resources in connection to work tasks and information needs. Further, search task processes are discussed as one means of using information resources and satisfying information needs. (Papers I, III, IV, VI.)
4. **What characterises queries in work task performance, and what are the effects of task type and complexity on the queries?**
   Queries are analysed in terms of their frequency, length and type in varying work tasks. (Papers I, V.)

This thesis contributes to the knowledge of *real-life* searching. As Pharo and Järvelin (2006) suggest, textbook descriptions of information searching may be over-rationalised. It should be remembered that, at least based on my experiences observing the participants, the phenomenon called IR or information searching is something that the participants, that is the searchers, do not often even reckon as such. For them, it is just a natural phase of work task performance.

Analysing the features of authentic work tasks and their connection to information searching is a crucial step towards better information (retrieval) systems and better information environments as a whole. Answering the above research questions reveals some relevant work task features in terms of information searching, what kinds of information needs people have and how the existing information environment is exploited in task performance.

One thesis is not enough to reveal the true nature of task-based information searching. The main contribution of my thesis is on the *empirical* findings that elaborate and broaden the previous understanding of the relationship between work tasks and searching. Additionally, I intend to contribute to the following:

- Methodological knowledge: I hope that my experience with various methods of data collection and analysis will benefit further research in the field.
- Contribution to the design of work and search tasks for IIR experiments: I hope that my findings and experience in the field will contribute to future researchers in forming more realistic experimental designs.
- Contribution to theory formation: This is certainly the hardest part to contribute to in a single thesis. However, I hope to be able to reveal some generalisable tendencies of information searching that can be tested further and used as steps towards a holistic model of task-based information searching.

The structure of the thesis is as follows: In Chapter 2, I discuss the various terms used for studying phenomena related to information searching. I also go deeper into the most important concepts of the thesis and the research approaches to task-based information searching. Chapter 3 covers research design with information about participants, data collection and analysis methods, and finally briefly presents the contributed papers. In Chapter 4, I answer the research questions in detail by combining the results of the contributed papers. The findings are also compared with earlier research. Chapter 5 includes a discussion of the most important findings and their contribution on a more general level. Also the limitations and implications of the thesis are discussed. This is followed by the final chapters with Conclusions and References.

2 Earlier research

In this section, I discuss the key concepts of the dissertation. First, I am going to look through some of the labels given to the research related to information searching in order to set my own study into proper context. Then I briefly discuss work and search tasks, information needs and information resources as concepts. This is followed by a presentation of empirical research approaches related to studying these concepts as phenomena, following the outline in Figure 2.

2.1 How to name it?

The process of trying to find information and satisfy one's information needs has had many labels in earlier research. Next I map the use of some of them with help of examples in order to better delimit and discuss the scope of the present thesis. It is important to state explicitly the intended position of the study since the approach chosen follows all phases and decisions made during the research process.

According to Fidel (2012, p. 17-21) (human) **information interaction** is a discipline investigating all kinds of situations where information and humans are in contact. Fidel (2012) argues that library and information science is a research community that has clearly taken human information interaction into its research agenda in the form of information behaviour studies. Ingwersen and Järvelin (2005) emphasise in their definition that information interaction is essentially a process between *cognitive actors*. Järvelin *et al.* (2015) discuss (task-based) information interaction as taking place both cognitively and in behaviour, and covering phases from task planning to the possible reporting of task results. Information interaction is even included in a name of a conference (Information Interaction in Context, later merged into Conference on Human Information Interaction and Retrieval) that also used to cover, and aimed at bringing together, a wide range of information-related disciplines from information seeking to IR system design. Toms (2002), however, provides a narrow understanding of information interaction as using an information system. In Fidel's (2012) terms this would be closer to human-computer interaction.

Bates (2010, p. 2381) argues that **information behaviour** is the correct term to characterise a wide range of information-related activities, typically seeking for information and using it. Similarly Wilson (2000) states that information behaviour is a wide umbrella concept that includes information seeking, retrieval, and use. Wilson (2000) adds that it does include passive information gaining (without intentions for further use), as well. Among others, Bartlett and Toms (2005) have applied the model of information behaviour in an empirical study.

Based on the examples given above, it seems that compared to information behaviour, information interaction is an all-encompassing construct with a different approach. Information behaviour is, as its name suggests, most interested in behavioural aspects whereas information interaction intends to go beyond them, as well (Fidel, 2012). However, the difference seems subtle and fickle in practice. "Information interactionists" still discuss *behaviours* whereas "information behaviourists" discuss various *interactions*. Blandford and Attfield (2010) discuss *interacting with information* quite thoroughly without giving an exact definition of what it is (or, more suitably, what it is not). However, implicitly their approach seems to be somewhere between Wilson's (2000) information behaviour and Fidel's (2012) information interaction.

Tabak's (2014) critical review discusses current research of **information practices** but does not define it. However, the review implies that current information practices research is interested in arguing whether context (environment) or the human user (cognitive aspect) – or both – is the main factor in shaping information practices. Fulton and Henefer (2010) state that information behaviour is the rival approach of information practice research: information behaviour focuses on users whereas information practice considers sociocultural context more important. In this respect it seems that Tabak (2014) actually discusses the differences between information practice and behaviour research. Information practice approach has been used empirically by, for example, McKenzie (2003) in a study of everyday-life information seeking, and Fry (2006) in a study of information practices in the scholarly domain. A difficulty in defining information practices, behaviour or interaction unambiguously lies in that they are used as names for both specific theoretical approaches or paradigms, and concrete actions that people perform in order to find information (in which meaning they are especially liable to interchangeable use).

Similarly to information interaction, **information access** is an interdisciplinary research area that has applications within library and information science. For some authors, it belongs to the research of information ethics. In this respect, information access considers the aspects of availability of information both in terms of functioning of information infrastructure, and the human right to access and produce information. (Oltmann, 2009.) Kumpulainen and Järvelin (2010) apply quite a different definition. To them, information access covers different ways of using information systems in order to find information as well as the non-computer-based information seeking. This is close to the definition of *information searching* applied in the present thesis. Also Hansen (2011) defines information access similarly, as being part of *information handling*. Other types of information handling are, according to Hansen (2011), for example information organisation and creation. Buckland (1991) lists that gaining access to information includes six steps or aspects: a source must be identified and physically accessible to the user; the user has to understand the contents of the source as well as accept them; and further, the access depends also on the costs to both the user and the provider of information. Kumpulainen and Järvelin's (2010) understanding can be seen implicitly based on Buckland's (1991) view though in practice they analyse the physical accessibility in the form of realised use.

Information seeking covers human actions to find information by using all kinds of information sources; and it is a subset of information behaviour (Ingwersen & Järvelin, 2005; Wilson, 1999). From the viewpoint of the seeker, it is best modeled as a developing process with various phases (Kuhlthau, 1991). Fidel (2012) claims that information seeking is always intentional (otherwise, it is not information seeking). Erdelez (1999) discusses *information encountering* which happens when information is found though it was not actually sought for.

Information retrieval (IR) is typically used to mean quite technical aspects of fetching information, that is documents, by using an (electronic) IR system (Ingwersen & Järvelin, 2005). According to Frakes and Baeza-Yates (1992), IR belongs to the field of computer science. Belkin (1993) maintains that IR is primarily a part of information seeking process, and thus the user and her interaction with the system should be in the focus of IR system design.

The user with her contexts is involved in **interactive information retrieval** (IIR) (Ingwersen & Järvelin, 2005). Following what Belkin (1993) already stated, Ruthven (2008) argues that IR is actually IIR because most IR systems are used interactively. Borlund and Ingwersen (1997) proposed simulated work task situations as a new evaluation model of IIR systems. In them, the user's context is taken into account by providing a contextual search situation to the searcher (Borlund & Ingwersen, 1997).

I have decided to use the term task-based **information searching** to describe what I study. The decision is mostly based on Vakkari's (2003) review named *Task-based information searching*. He does not exclude information seeking studies, but his emphasis is on interacting with electronic information systems, namely (I)IR systems. This is exactly the approach in my study, as well. Especially nowadays IR and information seeking are nearly inseparable in field studies since electronic information systems play a major role, and one basic way of using them is querying. Hansen (2011) has a similar idea of intertwining information seeking and IR in real-life working environment but he simply calls it *task-based information seeking and retrieval*.

Typically, *searching* is used as a verb to describe that people try to find information using an information retrieval system (Jansen & Rieh, 2010; Pharo, 2002; Wilson, 2000). Thus, the term used for this kind of searching could just as well be *retrieving information*; perhaps it would sound too straightforward considering that humans are involved. Wilson (2000) states that information searching (behaviour) means basically using any kind of information systems. This certainly depends on what one considers forming an information system. Allen (1996) argues that the generally accepted meaning of information system as a means to access electronic documents is just a small share of an actually relevant meaning of an information system. The present thesis follows the more narrow meaning of information system though searching is understood broadly.

Initially, information searching did not have the additional supposition of searching in electronic systems. For example Kuhlthau's (1991) classic model represents *information search process*. Also Allen (1996) and Fidel (2012) use the terms information seeking and searching interchangeably. Byström and Hansen (2005) add an interesting angle to the above discussion. They discuss information *seeking* tasks that are fulfilling a larger information need. Information *search* tasks are smaller subtasks, performed in a single session, be it computer-based or not. *IR* tasks then are special cases of search tasks because they are performed using a search engine. (Byström & Hansen, 2005.)

Based on the discussion above, I had several naming options to choose from. Perhaps human information interaction would have been too broad as an interdisciplinary umbrella concept. Information behaviour is already close, as is information access in the sense Kumpulainen and Järvelin (2010) used it. However, since it may also refer to (ethical) questions of how to provide access to users, it seems unsuitable for the present study: I analyse the actions the participants self perform in order to access information, not how the information is provided to them. Information behaviour on the other hand would not really reveal the focus of the study. The same problem lies with information practices. Behaviour and practices as names would carry an implicit meaning of focusing on either user or her context, but my focus is task-based. Work tasks are not directly user- or context-centred: tasks are formed in and ruled by the organisational context, but performed by individuals with their unique features. My thesis belongs clearly to the field of information seeking, but as a title, that would possibly miss the additional focus on IIR, and thus the audience of IR community. As the study involves human partipants, it could have been called IIR, as well. However, IIR would more likely miss the audience and focus of information seeking which is constantly present. Further, IIR associates with an extension of traditional IR towards users (*cf.* Kelly, 2009, p. 2) which is not the starting point of the present study. Rather, the mission is to combine ideas of both IR and information seeking research. **Task-based information searching** associates with an active process of using information resources. This includes analysing the querying in information systems but covers for example the use of human sources, as well. Task focus is explicit, and in the present sudy, tasks are authentic work tasks.

2.2 Work tasks and information searching

Work tasks form one's work duties and they are performed with a specific goal or output in mind (Byström, 1999; Vakkari, 2003). This reasonable, abstract definition is near layman understanding of the essence of work tasks. Without a doubt, the practical definition, that is, the operationalisation of work tasks varies between studies. A useful separation as presented by Byström and Hansen (2005) is between task assignments and task processes. This separation distinguishes "objective" parts of work from "subjective" parts of work, that is, how these objective parts are conducted in practice. On an abstract level, work consists of duties, such as teaching a course, designing a product, finding new customers and keeping track of income and expenses. These are something people might tell about their work in an interview, or these kinds of task assignments might be given to participants in a test setting.

In the present thesis, the focus is on the subjective parts of work, that is the manifestations of task assignments. In the questionnaires used, the participants were always describing their tasks at hand, that is the concrete processes they are performing. As the intention is to explore real-life information searching, focusing on subjective work tasks is a natural choice; though more abstract work duties or assignments exist, their hands-on performance can only be observed through subjective work tasks.

Byström and Hansen (2005, p. 1051) show in a figure how work tasks include **search tasks**. In their framework, a search task is performed in a single session, whereas an information seeking task is performed often using several sources in several sessions in order to meet a whole information need. Both information seeking and search tasks can be performed using electronic or other sources. (Byström & Hansen, 2005.) My operational definition of search tasks covers only cases where *queries* are issued to an information system; not other ways of using electronic information systems (such as browsing or following direct hyperlinks), nor the use of non-computer-based sources (such as asking a colleague). These restrictions are based on the interests of the present thesis and follow a rather typical understanding of a search task in (I)IR research.

A typical operational definition of a search task in a test situation is to give the participants strict time limit and a task assignment with an explicit, well-specified information need: finding an answer or relevant documents about a topic (*e.g.* Aula, Khan & Guan, 2010; Bell & Ruthven, 2004). Often the participants are allowed to use only a single system for searching. In case of log studies, search task boundaries are derived from the logs based on automatically judged query similarities (topics) (*e.g.* Kotov *et al.*, 2011), or search tasks are operationalised as search sessions limited by time frames (*e.g.* White, Dumais & Teevan, 2009).

The operational difference between work tasks and search tasks is not always made clear in earlier research. For example, simulated work task situations (Borlund & Ingwersen, 1997; Borlund, 2000) present the participants with a *problematic situation* similar to larger tasks in work or leisure time. However, what the participant is actually expected to do is to form a query in a system and to find relevant documents following the instructions. Despite its originality and merit, this approach mixes the idea of performing a larger task with actually studying rather conventional, assigned search tasks; the relationship between these two is oversimplified. Because the work task is not really performed (only the information searching part is), it will remain as more or less effective background context.

Especially if the simulated work task is abstract, that is, describing a prevailing interest rather than an *ad hoc* situation, there is a remarkable gap between the more abstract description and the actual performance that is expected from the participant. If the participant is provided a background at the same time as a quite indicative, straightforward "information need", we cannot know how she would have formed the information need herself based on the larger task or interest. Thus, also the intended meaning behind the background description (the work task) is left quite open. Should it affect relevance assessments, for instance? One given explanation is to get the participants better motivated for searching while still maintaining controllability (Borlund, 2000). Li (2008) used six simulated work tasks in her study. They were designed based on students' real tasks and varied in their complexity and type. The study merited in that the larger tasks' description and more detailed instructions of performance ("the search task") were quite well bridged. (Li, 2008.) Still, the tasks were typical study assignments and search-intensive (*i.e.* searching uppermost).

Task complexity has been an object of interest in studies of information searching. Wildemuth, Freund and Toms (2014) argue that task complexity and difficulty are the most acknowledged task features. They analyse both empirical and conceptual papers discussing information searching and task complexity or difficulty (Wildemuth *et al.,* 2014). Liu and Li (2012) maintain that especially objective and subjective task complexity, on the one hand, and task complexity and difficulty, on the other, are often confused.

Campbell (1988) argues that in research, task complexity is used to refer to the features of the task performer (subjective complexity) or the task itself (objective complexity), or sometimes a combination of these two. For example, Liu and Li's (2012) framework focuses on the so-called objective task complexity, but in my opinion objective and subjective complexity go together in the sense that same task features can affect both. Task complexity is not an isolated task feature but affects task performance in combination with other features.

Gwizdka and Spence (2006) tested subjective task difficulty, objective task complexity and task performance in an experiment where students conducted fact finding tasks on a university's website. They found that the complexity measures were correlated. Both affected website navigation but subjective task difficulty more. However, the conclusion was that these results were biased; the participants were not able to reliably estimate complexity because other variables affected their estimates as well. (Gwizdka & Spence, 2006.)

Similarly, Maynard and Hakel (1997) found that objective and subjective task complexity correlate positively with each other and the time to perform the task, but negatively with the success in the task. Task complexity still affected negatively task performance when the effects of cognitive abilities were controlled.

Interestingly, the participants' prior experience of similar tasks did not affect performance. The researchers concluded that since the correlation between complexity measures is not strong, these two measure different phenomena; especially that subjective complexity is under the influence of other factors besides the objective complexity itself. However, subjective task complexity also seemed to mediate the effects of objective complexity on task performance. (Maynard & Hakel, 1997.)

Earlier studies often seem to prefer objective complexity measure. Still, if task performance is heavily affected by the performer's impression of complexity - whatever its cause - it can hardly be ignored. However, complexity is even by its very nature an elusive concept that is handled from varying starting points in each study. The comparison between studies is only made possible by carefully described methods sections.

As stated above, previous studies show that there exists a phenomenon called task complexity and that it affects information searching. A whole range of studies has found the effects of task complexity, though approached and operationalised in a variety of ways. In controlled study environments, it is possible to assign tasks to participants and deliberately alter their complexity. However, what people perform in their daily work are subjective work tasks if they have at least some control over how they structure their work, which is often the case in knowledge work and the fields studied here. Therefore, the complexity of their tasks cannot be measured only objectively. The subjective complexity may be related to, but not completely depend on, any objective complexity construction. In the present thesis, only subjective work task complexity is analysed.

In addition to task complexity, also **other task features** have been of interest in earlier research. I will give a selective view on the studies that are relevant to my study. A distinguished review about task features is Li and Belkin (2008). They list that tasks vary in their source, the performer, time-related aspects, the end product, performance process and goal of the task. Tasks also vary in their objective complexity and in their performer's perception. (Li & Belkin, 2008.) Liu and Li (2012) present a similar framework of task components, such as goal, input and process, and they even present how these components are connected to task complexity. Allen (1996) provides another viewpoint by not concentrating on the work tasks or search tasks of people but breaking them down as information tasks that describe the interaction between the source contents and the human (*e.g.* scanning or evaluating). Xie and Joo (2012) categorise "work tasks" into scholarly, occupational or popular (leisure time) tasks. Our task type categorisation that is presented next includes only occupational tasks and some of them are related to scholarly work in the present data.

I formed a data-driven work task type categorisation that includes categories for communication, support, editing and intellectual tasks (Papers IV-VI). This categorisation is entirely based on Data Set B: it was so large and heterogeneous that I felt that the effects of work task complexity could and should be elaborated with other potentially influential work task categories. There was a satisfactorily homogeneous pattern of how people were naming their tasks across work roles and fields, and I exploited it. However, the categorisation is based on more universal task features that go beyond the present data and are certainly not invented by me. (For further details, see Section 4.1.)

Adamczyk and Bailey (2004) took advantage of similar task features when they designed experimental tasks for study participants. They designed a writing task (similar to the *intellectual tasks* applied in the present work) which is creative; a proofreading task that comes close to our *editing tasks*; and a fact finding task which is more of a search task type. Algon (1997) presents a model with three levels of tasks. Though not totally overlapping, our categories are based on some similar ideas. Algon (1997) identifies administrative and communication tasks (under a *meta-task* category of interacting with others), which are close to our *support* and *communication tasks*, and three categories that resemble our editing and intellectual tasks.

In task performance, people encounter **information needs.** These needs trigger information searching; in fact they are the reason for it. In information studies' literature, information needs have been described in many ways. To name a few, Taylor (1968) discusses four types of information needs that differ in their level of specification; Dervin (1983) sees information need as a gap to be bridged with information; Belkin (1980) introduces the concept of anomalous states of knowledge (ASKs). Especially Belkin's (1980) idea of anomalous states of knowledge is fruitful from the information searching point of view, since the framework takes an explicit stand on how IR systems should respond to ASKs rather than concentrating only on representations of texts. In the present thesis, information needs actually only manifest through searching. If a person has an information need (understood as a thought or mental stage) but does nothing to satisfy it, nor states that she has one, there are not many means of catching it in a study that collects data of searching.

Wersig (1973) presents an idea of (objective) information requirements (*Informationsanforderungen*) of a situation as opposed to (subjective) information needs (*Informationsbedürfnis*). I do not analyse objective tasks as part of work duties, nor tasks' information requirements, but focus on their subjective occurences. I analyse information needs as goals behind a search task and the use of an information source. Naturally, these goals cannot be directly measured in the form of thoughts, but they are deduced from what participants report or do (for example query formulation). When observing the search tasks of participants, information needs were visible as *ad hoc* questions that pop up in the course of work. These are *applicational needs* using Feinman *et al.*'s (1976) term. There exist also other kinds of information needs that are more prevailing (Feinman *et al.* 1976; Savolainen, 1995), crossing the boundaries of individual tasks, but again these are not analysed here since the focus is on work tasks as concrete manifestations, not as representatives of recurrent types of tasks.

In the present thesis, information needs are analysed in Papers II and IV using a well-known classification of factual, known item and topical searching (Ingwersen & Järvelin, 2005, p. 291; Toms, 2011, p. 56). In Paper IV, an additional category called instrumental needs was needed. It stands for situations where the direct goal of searching was beyond finding (new) information (for example navigating) – also a commonly recognised feature in earlier studies as a counterpart to *informational queries* (Broder, 2002; Rose & Levinson, 2004; Jansen, Booth & Spink, 2008; Kumpulainen, 2014). The information (need) types applied in the present thesis are further discussed and compared to earlier classifications in Results section.

Information sources are the carriers of information contents (Ingwersen & Järvelin, 2005). Information source use is of continuous interest for information seeking research (for example, Taylor, 1968; Sonnenwald, Wildemuth & Harmon, 2001; Savolainen & Kari, 2004). Here I use also the term **information resource**. In authentic work task performance – especially in digitalised environments – the same information resource can act as a source of information and as a means to create or otherwise work with information. Thus, information sources are a subset of information resources. In Paper IV, we use the term *search media* to refer to the sources that are used by querying. They were not called *sources* because we wanted to remind the reader that we discuss only a special type of source, not all sources available.

An **information system** can act as a source of information or as a resource. I apply an *informal* definition of information system, following Mora *et al.*'s (2009) terms. Mora *et al.* (2009) criticise this approach but also give a good short overview on what information systems are in this "informal" sense. In the present thesis, an information system is understood as an interactive computer-based whole that consists of specific information objects and means to use them: typically to view, navigate, manage and process them. Information systems are used by humans so there needs to exist a user interface. (Similarly to *e.g.* Burton Swanson, 2010.) **IR systems** are information systems that are specialised in finding information based on user queries (Ingwersen & Järvelin, 2005; Larson, 2010). Clearly, the definition of an information system is quite broad. When discussing specific (types of) information systems, as is especially done in the empirical part of the study, I have chosen commonly used, appropriately narrow labels for them, such as *Web search engines*. However, in the case of organisations' computer-based resources, directly using the term *organisational information systems* seems convenient. The naming policy should not be understood as a proposition that there exist no other information systems than organisations' internal ones.

In Paper III, we introduce a small-scale classification of aspects of information resources and foundations of resource classifications used in information seeking studies. The idea is to provide a framework that goes beyond study-dependent labels of information resources. Being conscious and explicit of what features even data-driven information resource categories represent is important in understanding their use and contrasting findings between studies. For example, is the category about resource content or medium? Does it describe a specific data type? Are some resources considered to be more authoritative than others? The resource types found and applied in the present thesis are medium-based, and they often relate to questions of internality *vs.* externality. Organisations have their own internal resources but also publicly available resources are used. Different variations of communication are present. Resources can be accessed through a computer or otherwise.

2.3 Information searching as research object

Information searching as object of study has been approached in many ways in earlier empirical studies. One approach is to design new kinds of IR systems and methods and their components, and test their performance with automatic runs using a pre-existing test collection. This was presented as the one end of the continuum in Figure 2. This approach is important in the technical development of information systems but it is out of the scope of the present thesis. The difference is analogous to the one Allen (1996, pp. 1-2) made between user-centred and data-centred system design. Readers interested in the **traditional IR** are referred to

Croft, Metzler and Strohman's (2010) comprehensive overview of IR methods as well as to Voorhees and Harman's (2005) work presenting The Text REtrieval Conference, TREC.

A step towards naturalistic approach is adding **a user**, a searcher, into the study. Typically, the searcher is given a search task assignment and a time limit, and she has to perform the task by searching for documents using a single information system. The findings may concern the system's performance with real user, and/or the user's performance using the system, and/or performing the task.

Aula *et al.* (2010) used this approach to find out, whether performing a difficult (unsuccessful) search task is visible in the search behaviour. Similar questions were raised by Bell and Ruthven (2004) who used three different complexity levels of search tasks for analysing changes in the participants' search behaviour. Also Gwizdka and Spence (2006) altered the objective complexity of their search tasks, and analysed whether it affected search behaviour or subjective task complexity.

The above examples presented the idea of task complexity and its effects on search behaviour, but left several questions open. Would the participants have similar search tasks in reality? What about the possible work tasks, or other larger tasks, that bring forth the information needs and the search tasks? If the participants had an option, would they actually search this way, using this tool, and why?

In the narrowest sense, the user test approach is merely a small extension to the experimental setting without a user, if the human part is only a substitute to a script forming queries. Though the benefits of controllability are undisputed, the approach can give little information about task-based information searching.

Borlund (2000) states that real life is typically too noisy to be studied directly; instead, she proposes using **simulated work tasks** that – when carefully designed – enable both realism and controllability at the same time. This is of course a desirable aim when studying IIR, since (I)IR inherently includes the aspects of understanding how people search for information in order to support searching better, as well as trying to find technical solutions and designing new applications. As Blandford and Attfield (2010, p. 4) note, simulated work tasks and related IIR evaluation methods still focus on system performance.

Server-side log studies are realistic in the sense that the queries in the logs are issued in naturalistic situations without any artificial control by the researcher. Also huge amounts of raw data enable powerful statistical analyses. However, this all comes at the cost of contextual knowledge. The data do not carry explicit information about information needs, search tasks, or larger tasks behind the queries. Broder's (2002) study combined log analysis and pop-up questionnaire to find out the intentions behind the users' queries. He ended up stating that no more than every other query is informational – others are navigational or transactional by nature. This may hold true but does not reveal much considering task-based information searching. The questionnaire used got a relatively low response ratio, and it provided somewhat narrow options to choose from with quite far-reaching conclusions. Even if the participants had replied totally accurately, and Broder's (2002) further log analysis had succeeded in sorting out all search intentions behind each query correctly, we still cannot know what kind of task or situation formed the information need in the first place, and how the queries are related to these diverse situations and tasks.

Self-report methods refer to interviews, diaries and questionnaires; that is, data are representations of searching rather than searching itself. Without a doubt, these methods give valuable information especially about participants' intentions and thoughts, as these cannot be directly observed. However, participants' responses as the only data concerning searching may be biased. It is not easy to remember exact actions afterwards, and even if they were directly listed in a diary, for example, they may be rationalised. These views are based on my own experiences in data collection but similar problems have been reported in other studies, as well (*e.g.* Kumpulainen *et al.*, 2009). Especially when a participant has difficulties in recalling the searching, she naturally tries to form a coherent story. However, the performance itself may not be that coherent. Information is found in unexpected sources, work suffers from interruptions, people multitask and make mistakes. These things may affect searching though possibly forgotten to be mentioned, or left unstated since they are "of no interest for the researcher". It may also be difficult to accurately perceive how often a resource is used, for example.

Some studies combine features of both experimental and naturalistic field studies; these are called **controlled field studies** in Figure 2. For example, Pharo and Järvelin (2004) studied information searching in the Web in order to develop and test a new analysis method. In an empirical study, described in detail in Pharo (2002), students experienced in Web searching were searching information for their theses and these sessions were recorded. The tasks were authentic but the participants were asked to contact the researcher when they wanted to search the Web so that observation and video recording could be arranged. The data set was rather small and analysed qualitatively. The authenticity was increased by the fact that the students were able to use their own browser bookmarks and even allowed to do teamwork. (Pharo, 2002; Pharo & Järvelin, 2004.) At the time of the study it was not very common to have a personal computer or access to the Web at home, so the participants would most likely have had to plan the time for searching sessions anyhow.

Vakkari, Pennanen and Serola's (2003) study of university students' information searching was conducted in a similar manner. Students writing a research proposal participated in two search sessions, one at the beginning of the proposal process and one at the end. They used one bibliographic database to find relevant references for their work. The researches analysed how the searching was affected by search experience in the studied information system, and how the searching changed from the first session to the second. (Vakkari *et al.*, 2003.)

These two sample studies were heading towards a combination of realism and controllability, but they were somewhat limited in their scope. It would be beneficial to apply similar design to other real-life work tasks in addition to study assignments. Some studies have included the real tasks of students in studies using simulated work tasks (*e.g.* Borlund, 2000; Li & Hu, 2013). This enables comparing the two types of task, simulated and real, on a general level. However, the tasks the participants bring with them may be more of search task than larger task type depending on the instructions given; and related to their studies or leisure time rather than work outside full-time studying.

Next I will present a few studies that aim at approaching information searching from an authentic viewpoint, **in the field**. This approach is unique in the sense that it can provide information about how people really search and why (the context). However, a problem lies in the difficulty of study design and control, since basically anything can happen in the field (*cf.* Robertson, 2008). A naturalistic approach to task-based information searching requires real-time data collection that includes knowledge about the tasks the participants are performing. The participants' actions are not controlled in any way. They do the tasks at hand that they need to, and use the information resources available in their work place. Though the data collection obviously takes time and requires cooperative participants (Sonnenwald *et al.*, 2001), the data are deep and enable discovering also new phenomena.

Garber and Grunes (1992) studied art directors by interviewing them and observing them while they were discussing with customers and searching for suitable photos. The study did not analyse task features *per se*, but it is interesting because it combined several data collection methods and phases fruitfully and expediently. The study was a continuum of successive research goals: understanding the work and searching of the participants; forming a model of the searching process based on the observations; and designing and further testing and developing of a user interface for image searching. (Garber & Grunes, 1992.) This is a good example on how study methods support each other, and how a naturalistic approach is an important part of them.

Kelly (2004) conducted a longitudinal study with a few university students that were handed a laptop for research purposes. The participants searched as they normally would in their everyday life, named their tasks and once a week, in more controlled settings, paired their tasks with documents found during the week (Kelly, 2004). Unfortunately, Kelly (2004) did not analyse the tasks *per se* but rather how searching of each individual evolved. Thus, these findings are difficult to compare to other studies, especially in the sense of how task features affect information searching. Kellar, Watters and Shepherd (2006a; 2006b) conducted a similar study about students' Web related tasks. The everyday use of the Web was logged, and the participants reported what tasks they were doing. Kelly's (2004) and Kellar *et al.*'s (2006a; 2006b) approach was more likely to introduce leisure-time tasks than work tasks.

Huuskonen and Vakkari (2010) observed the work of social workers. They analysed how a client information system was used to support work tasks. However, they did not analyse how work task features affected its use.

Hansen (2011) conducted a thorough study about patent engineers' information searching. He exploited interviews, observation, diaries and logs. Work tasks were typified suitably for the domain, and also task knowledge (named also as *task difficulty*) was analysed. Work task performance was analysed in terms of information needs, sources, queries and relevance judgments. (Hansen, 2011.)

Kumpulainen (2013) directly observed and logged the searching of researchers of molecular medicine. She categorised the work tasks into complexity classes based on the participants' prior knowledge about each task, and analysed how it affected the problems encountered, search trails and work task processes.

As presented above, the field of (task-based) information searching and its basic concepts have been of much interest lately. However, realistic studies about work-related searching are still rare. Log studies provide quantitative credibility, whereas smaller-scale user studies or self-report methods provide more exact contextual information that can be connected to search actions. The present thesis provides both qualitative and quantitative data about searching in the context of tasks, and information seeking and (I)IR approaches are combined. Field data are rich and naturalistic. Using several data collection methods provides for a reliable view of real-life searching. Combining research methods in a single study is not common (Chu, 2015).

3 Research design

The thesis is based on two independent data sets, later referred to as Data Set A and Data Set B. The data collection and analysis methods are partly the same, so they are next discussed together. More detailed information about data collection can be found in the contributed Papers I-VI. Papers I-III are based on Data Set A, Papers IV-VI on Data Set B. Table 1 gives an overview of the two data sets. Data Set A was collected together with my coauthor Sanna Kumpulainen. Data Set B was partly collected in cooperation with Heljä Franssila and Jussi Okkonen (School of Information Sciences, University of Tampere) working in Professor Reijo Savolainen's Information ergonomics project (Franssila, Okkonen & Savolainen, 2014). In the latter case, it was agreed that no coauthorship will follow since we did not share any analysis phases nor any research questions or interests besides the data.

Table 1. Overview of the data sets.

	Data Set A	**Data Set B**
Time of data collection	February 2011 – May 2011	August 2013 - October 2014
Participants	6	22
Organisations	1	6
Work tasks	59	286
Interviews	n/a	Pre- and post-study
Direct observation	During all analysed work tasks; several sessions per participant	During one working day per participant
Task questionnaires	Pre- and post-task	Morning and afternoon
Logging	n/a	Transaction log and screen capture video
Volumes	38 observation sessions, 250 pages of handwritten notes	77 data collection days, 40200 rows of analysable transaction log

The study is designed to support understanding task-based information searching in the real-life context. The approach is explorative. Another important point is that we wanted to see the actual searching actions; rather conventional methods of only interviewing participants or analysing questionnaire responses did not suffice.

It should be remembered that real-life data do not come as neat and clearly labelled packages to the researcher but the analysis phase requires even detective work.

3.1 Participants

All participants were volunteers that received nominal recognition for their participation. The criteria for selecting participants was that they were knowledge workers using a computer in their work, and that they were willing to participate. As can be seen in Table 1, Data Sets A and B differ considerably. Data Set A is smaller and includes six participants working in municipal administration. Data Set B includes six organisations: three universities (5 participants; 30 data collection days; 101 work tasks), a municipal administration (10; 10; 47) and two companies (7; 37; 138). The recruitment process varied by organisation. In Data Set A, the first contact was to the organisation in question, and the participants were internally selected. This was the procedure in one of the companies and the municipal administration in Data Set B, as well. Other participants were directly contacted and asked to participate, naturally with permission on behalf of their employers.

The participants' traits related to their age, education or job experience *etc.* are not analysed in this dissertation. The participants represent various age groups within working age, from their mid-twenties of age to near the age of retirement. Most participants are highly educated and have several years, some even decades of experience in their current and/or similar work tasks in the current and/or another organisation. The participants include four superintendents. Six participants are males.

The organisational structure of the two city administrations studied varies but the basic functions are similar. The participants in city administrations work as managers, planners, specialists, officers and secretaries within various sectors providing services for citizens, such as health and environment, and some sectors also provide internal services. The participants' duties include, for example, communication, human resource management and preparation of decisions.

The two commercial companies are a small organisation providing services for customers and a large organisation providing services and goods. The participants in these organisations represent various aspects of knowledge work. For example, they take care of customer relationships, financial management and human resource management. They design, develop and supply goods and services and their assortment.

The participants from the three universities have duties related to research and teaching. They represent fields of pedagogy, arts, engineering and natural sciences.

The participants together do not represent any homogeneous group but are a self-selecting convenience sample. This approach has three reasons. Firstly, the practical limitations include that it is not easy to recruit enough participants for this kind of intense and gratuitous study. The quantitative aspect of data analysis was considered crucial for the goals of the study, so the more participants, the better.

Secondly, since this is an explorative study analysing domain-independent work task features and searching, we had no initial reason to expect that they are affected by a specific participant feature. This was also out of the scope of the study. In fact, typical earlier studies have selected a small and really homogeneous set of participants (for example, undergraduate students from the library and information sciences in their twenties for easy availability) and make quite far-reaching conclusions about their actions.

This leads to the third point. Studying a heterogeneous group of people lets us reach findings that possibly are applicable to a range of knowledge worker groups. Without a doubt, it would have been ideal to study several large, same-sized groups of people, each group representing a relevant feature, and compare and join their results. Since this was not feasible, the present approach was considered the next best option.

However, I am aware that the decisions made are rather unusual and have their limitations. It is clear that organisations differ in several respects: they are of different sizes, they have varying goals of operation, work roles and thus work tasks differ *etc*. Especially on a substance level, it really makes a difference whether one is planning a marketing strategy for a small company, designing a new collection of items for a large company, writing up a record, writing a news article, conducting scientific research on arts or engineering, or filling in work hours in an electronic information system. Further, some people have subordinates, some have a lot of work experience, some are more motivated than others, and even personal life can affect the work. The list of potential differences between organisations, jobs and people can continue almost endlessly.

Still, the information-intensive work tasks studied here have several features in common. For example, information is a key factor, it acts as both input and output of work; the same individual has tasks that vary in (subjective) complexity and contents; several types of tasks are common across organisations though perhaps their frequency varies. The data-driven task type categorisation applied in this study shows that people in various organisations have administrative tasks, produce new information and information objects and later develop them, and that interaction with colleagues, customers and other parties form a significant part of their work.

3.2 Data collection methods

3.2.1 Direct observation

According to Chu (2015, p. 39), observation is not a quite extraordinary research method even though it is used relatively seldom. Direct observation is a method that provides the researcher a holistic understanding of the observed work. The method is also referred to as *shadowing* (McDonald, 2005; Czarniawska-Joerges, 2007). However, especially in Data Set B, I prefer using the term *observation* because I did not make explicit separation between shadowing and other observation methods while collecting the data. Furthermore, shadowing seems to be more connected to larger etnographical and longitudinal studies. The present study is not etnographical in the sense that my focus was quite narrow; and though the observation in Data Set A was somewhat longitudinal (several sessions with participants), in Data Set B it was not (only one, day-long session per participant).

For Data Set A, I and my coauthor Sanna Kumpulainen observed the participants during all the work tasks they were willing to include in the data set. We divided the participants so that I observed the work of four, Kumpulainen the work of two. Initally Kumpulainen had one more participant whose data collection was not successful and had to be ended after a few sessions. I received Kumpulainen's original shadowing notes and merged them with my own for the analysis. In Data Set B, I observed the work of all participants during one day each, and I was the only observer.

The observation method applied was similar to the method of Kumpulainen *et al.* (2009). The observer sits next to the participant, closely following her work and taking notes when necessary (the details of note-taking depend on other data collection methods). The researcher also takes recordings if the participants explains something that is hard to catch on the fly by taking notes. The observation in Data Set A was supported by pictures taken by an automatic camera and worn by the participants during the observation sessions. The camera was not considered necessary in Data Set B because of the logging and screen capture software used. In Data Set A, all actions (including queries and window switching) had to be written down by hand whereas in Data Set B, the notes only had to support understanding the log. Also all non-computer-based information resources were listed by hand in both cases but were analysed further only in Data Set A.

Direct observation has its drawbacks, such as the observer effect (McDonald, 2005). However, observation proved irreplaceable also in Data Set B, considering the aim of the study to understand real-life searching and place it in its context. One-day sample of the participant's work tasks and ways of working made a great contribution to understanding what they were doing during the other data collection days, as well. For example, one participant received a lot of email inquiries. During the observation day, I saw how replying to these emails could take up half the working day, leaving little time to the core work of the participant. Without seeing it with my own eyes, I would not have been able to understand this based on the log. Such observations are important for correctly spotting the work tasks in the data.

3.2.2 Interviews

Interviewing is particularly suited for collecting qualitative data, and supporting other data types. It is a common method for collecting data about people's behaviour, including information related actions. For example, Allen and Wilson (2003) interviewed their participants when analysing the experiences about organisational information overload. According to Chu (2015), interviewing has lately been in the top-5 reserch methods of articles published in two major journals in the field, Journal of Documentation, and Library and Information Science Research.

We used interviewing when collecting the Data Set B. Each participant was interviewed before the data collection phase, and those who had participated for more than one day, were also interviewed afterwards. Interviews were not analysed *per se* but they had a major role in understanding the log data and the participants' actions.

An opening interview was semi-structured. The interviews' intended contribution for the present thesis work was to obtain background information about the participant, her work and information environment. More detailed questions concerned information ergonomics. As this was the case, we agreed that in case of overlapping schedules, such as an observation day, Heljä Franssila conducted the opening interviews and I received the recording of them afterwards. There were nine of these interviews, together we conducted nine interviews and the rest I conducted by myself, since four participants were only taking part in my thesis project. Naturally, in these cases the interviews solely dealt with questions relevant to the present thesis.

A few weeks after the data collection phase had ended, I met with the participants for the exit interview. As stated above, I met only those who had participated for more than one day because if the data collection phase was only for one day, it included direct observation, and thus further interviewing was not needed. I had conducted a preliminary analysis of the data before the interview. With each participant, we discussed detailed questions especially about work task boundaries and information searching so that I was able to understand the search actions, and link the work tasks to the right snippets in the log. All exit interviews were conducted by myself alone or together with Heljä Franssila.

3.2.3 Questionnaires

Questionnaires typically provide quantitative data (Sonnenwald *et al.*, 2001, p. 67) which is however prone to mistakes (Kumpulainen *et al.*, 2009). Questionnaires are a popular research method in library and information science, being the second and third most used research method in the top journals of the field (Chu, 2015). We used electronic questionnaires as one data collection method, and in connection with other methods, they seemed to work well. The questionnaires' main mission was to provide information about work tasks the participants performed. For practical reasons, the use of questionnaires differed in the two data sets though the basic idea was the same. In the questionnaires, participants described their tasks and the resources used, and estimated task complexity with percentage figures.

In Data Set A, the participants filled in two questionnaires *per task*, one before the task performance and one after it. Thus, during the observation sessions they had to indicate task boundaries, decide when a task is finished and when another starts. The questionnaires are appendices of Paper II.

In Data Set B, the participants filled in two questionnaires *per day*, one when they came to work in the morning and one before they left work in the afternoon. Thus, the participants had to list the tasks they thought they were going to do as well as remember the tasks they did. This seemed to be no problem for them, since this was something they probably do anyhow (planning the day as well as recalling what was done and what was not) though perhaps not in a sense of a physical list. The questionnaires are appendices of Paper IV.

3.2.4 Transaction log data and screen capture video

Recording the exact actions of participants is a practical way of collecting data about information searching. Field studies and user experiments utilise client-side logging (*e.g.* Borlund, 2000; Aula *et al.*, 2010; Hansen, 2011; Kumpulainen, 2013). Search engine use may be analysed by using server-side logs (*e.g.* Broder, 2002; for a review, see Jansen, 2009). We used client-side logging, that is, the logging software was installed locally on the participants' computers and it collected information about all interactions on the computer.

The organisation studied in Data Set A did not allow installing any data collection software on their computers. This was problematic considering our interest in information searching. In Data Set B, we decided to include only organisations that would allow logging. We used a commercially available logging software and a commercially available screen capture software.

Screen capture means that the software recorded a continuous video of the participant's screen, that is, the video included everything that the participant saw, and the video was as long as the working day. The transaction log collected information on the active window. It recorded the time stamps (when the window was opened and when inactivated), duration of visit to the active window, the name of the software (*e.g.* the name of the Web browser or the local software), and a more specific label (*e.g.* the URL or the name of the file). It did not collect information on key strokes, mouse clicks or movements. Neither did it collect any contextual information: work tasks, search tasks and queries were all later intellectually identified (though some queries to Web search engines were directly detectable in the URLs that included the word *query*). The logging software had a feature that it asked the participant what she had been doing if there was an inactivity of more than ten minutes. The participants were advised to write a few words if possible: it helped us to keep track that the logging worked (instead of randomly missing events), and there was the possibility that knowing that the participant for example met a colleague in order to perform a specific task was of later use.

The transaction log software and the screen capture software were installed on the primary computer of each participant. Transaction logging started and saved events automatically, but screen capture needed to be started and saved by the participant. The participants were given detailed instructions on how to use the software and they were encouraged to call or send email at any time for further instructions if needed. They were able to pause and relaunch the recording of both the log and the screen capture. The transaction logs were also modifiable: events could be deleted or named differently by the participants. They were also able to put *private* tags in the log if they wished the researcher to delete something for them, or they could otherwise inform us about need for deletions. The screen capture video was saved as one unstructured video file, so editing it was more laborious and thus not performed by the participants. Though the participants had the option to pause the recording, they sometimes wanted the videos to be cut or blurred aftewards, and it was done according to what they wanted. The fact that the participants were able to control the data collected was indispensable. This is a question of research ethics, and it is often a precondition in getting access to organisations and finding willing participants.

3.3 Analysis methods

Explorative analysis of field data is an iterative and creative process. Here I will give an overview of the analysis methods used. Each contributed paper includes more detailed information about its own methods. In both data sets, I had a great deal of rich raw data. To start with, the data were qualitative in the sense that they featured few readily usable figures to start making calculations. Thus, the data had to be quantified by structuring it, finding incidents, giving them names and grouping them. Though there exist acres of literature about analysing qualitative data, the literature cannot provide ready-made instructions usable in all possible studies. As this was not a replicate of any earlier study either, I had to create tailor-made ways of analysis. However, though created *ad hoc* concerning details, the analysis methods used are, on a general level, common to many studies that similarly try to find patterns in human behaviour. That is, for example, going through all available data, pondering on suitable variables and categorisations and testing them on subsets of data. Yet I did not strictly engage in a school of thought considering the analysis methods used since the methods had to be suitable for the data and the goal of the study, not the other way round. I do not see a principled conflict between quantitative and qualitative methods either - they should be used together whenever possible (Martzoukou, 2005).

Cleaning my data and preliminary analysis took several rounds. This included, for example, going through the data to get an overall picture (such as viewing pictures, watching videos, reading task questionnaires), deleting unnecessary data from the log (such as extra days not present in the questionnaires) and transcribing notes and interviews. The next step was to connect work task labels to chronological data correctly. This was a crucial phase of analysis, since the study operates with work tasks as unit of analysis, and depending on data available this demanded even detective-like work, following clues and piecing them together. Next, work tasks were assigned relevant features, such as complexity. Similarly, I had to decide how to describe real-life searching. I had to choose variables and phenomena that are meaningful considering the research questions, of interest to the research community, and that can be reliably analysed given the data available. For qualitative variables, suitable categorisations had to be formed. After that, the data were ready for quantitative analyses and statistical tests that are described in individual studies.

3.4 Introduction to the original research papers

Table 2 overviews the design of the contributed papers of the thesis work. Table 3 summarises their main results.

Table 2. Overview of the contributed papers.

Data set: paper	Main data	Independent variables	Dependent variables
A: I Task complexity and information searching in administrative tasks revisited	Observation field notes	Perceived *a priori* knowledge, perceived task complexity	Information resources, problems, query-based searching
A: II Task complexity affects information use: a questionnaire study in city administration	Questionnaire responses	Perceived task complexity	Information types: internality, expected/dropped/materialised/new
A: III Expected and materialised information source use by municipal officials: intertwining with task complexity	Questionnaire responses	Perceived task complexity	Information sources: expected/dropped/materialised/new (and information types in sources*)
B: IV Search task features in work tasks of varying types and complexity	Log, screen capture	Perceived task complexity, task type	Search tasks: main search medium, number of unique search media, information need, performance process
B: V Queries in authentic work tasks: the effects of task type and complexity	Log, screen capture	Perceived task complexity, task type	Queries, number of search tasks
B: VI Work task types, complexity and usage-time of information resources: a field study of relationships	Log	Perceived task complexity, task type	Usage-times of computer-based information resources

* No complexity-wise comparisons.

Table 3. Main results of the contributed papers.

Paper	Main results
I	Perceived complexity is more clearly connected to task performance than perceived *a priori* knowledge. The number of queries increases with task complexity, and information resources used become more flexible.
II	Growing task complexity increases the need for topical information, whereas it decreases the need for facts. Known items stay unaffected. External information is in a minor role but it is used more in complex than in simple tasks.
III	The actual use of organisational information systems drops, and the use of Web and *other sources* increases with growing task complexity. Growing task complexity increases the share of Web among unexpected sources. Organisational information systems are used the most. Human sources are the most unexpected source type. Information aggregates are the most expected information type in all sources except organisational information systems where known items are expected the most. In email, the focus on information aggregates changes to known items in materialised use.
IV	Most search tasks are conducted with one query. All main search media are used roughly as much aside from PC. Task complexity is not connected to the main search media. Factual needs are most common. The share of topical needs peaks in the most complex tasks, instrumental needs peak in the simplest tasks. Single search processes peak in the simplest tasks, developing processes in the most complex tasks. Work task type is connected to the distribution of main search media and information needs: Instrumental needs are common in communication tasks, factual needs in support tasks, known item needs in intellectual tasks. The Web is used frequently in support tasks, communication media in communication tasks. Intellectual and support tasks include a large share of developing processes, single searches are common in communication and editing tasks. Task complexity's effects on information searching vary between task types.
V	When work tasks become more complex, people search more in terms of queries and search tasks, but the queries shorten. Intellectual tasks include more search tasks, which further include more queries than other task types. Queries are shortest in communication tasks and longest in support tasks. Queries are overall well-specified since proper names as search keys are common.
VI	With growing task complexity, the duration of tasks increases, mainly caused by the increased use of PC resources. Resource use in support and intellectual tasks is more prone to the effects of task complexity than in other tasks. In support tasks, participants use communication resources more when task complexity increases. In intellectual tasks, the use of local resources increases and the use of organisational resources decreases with growing task complexity.

4 Results

This section reviews and discusses the empirical results I obtained throughout the thesis project. The section is divided into four subsections according to the research questions (see Section 1.2). Several papers are discussed at the same time. In each section, I present the findings of the original papers, draw some conclusions about them and compare the findings to related research conducted by others. However, the more detailed the findings that are discussed, the smaller is the number of earlier studies that enable comparisons. Therefore, I have had to make some broad generalisations when comparing studies and findings, such as generalise findings over different participant samples or interpret various independent variables from a perspective that may be unexpected but brings them closer to my independent variables in a justifiable way.

The subsections are as follows: First, I analyse the work tasks as context for searching: how work tasks can be categorised and what kind of information resource use they include overall (research question 1). Second, I move to work tasks' effect on information needs (RQ 2). Third, I analyse the effects of work task features on information resource use (RQ 3). Fourth, searching is discussed in terms of the effects of work tasks on queries (RQ 4).

4.1 Overview of work task features and performance (RQ 1)

In this section, I discuss the findings concerning work tasks as a context for searching: what are the features of work tasks, how many and what kinds of information resources are used, how many search tasks they include and what problems are encountered.

Work task complexity was measured as an aggregate variable, *perceived complexity,* which means that the participants estimated themselves the direct complexity of the tasks as well as their knowledge concerning the task. It was considered that work task complexity is in itself a complex construct that is best measured using several variables rather than relying on post-task complexity, for example (similar approaches are used by Byström (1999, p. 69) and Kumpulainen

(2013, p. 35)). Work tasks in the data were rather simple than complex; really complex tasks were rare. A similar trend is visible in Kumpulainen's (2013) data though the complexity was then judged by the researcher. It is understandable that complex work tasks are rare. People perform somewhat similar tasks from day to day (as they do have a specific occupation and work role) and they learn to do them even if tasks seemed complex at first. Having people doing extremely complex work tasks all the time ("jack-of-all-trades") without specific areas of duties in an organisation would be inefficient.

Task complexity is connected to the length of the task: the more complex the task, the longer it takes to perform it, and this can be connected to two different points. Complex tasks are often creative or laborious and thus time consuming by nature. Another point is that complexity may be connected to lack of personal skills and knowledge, which delays task performance.

Work task types. Work tasks in Data Set B formed four *task types* based on the short descriptions given by participants. Interestingly, all participants were naming their tasks on the same level of abstraction. Perhaps this is partly caused by the fact that they listed their tasks each day, *i.e.*, the tasks were concrete actions cut into pieces with maximum length of one day. In Data Set A, where this restriction was not present, the variance considering the task's length and task description was larger (many year's planning project *vs.* planning a presentation).

Communication is a task type that highlights the communicational aspect of a task, such as going through emails, teaching, and taking part in a meeting. Algon (1997) discusses communication tasks in a similar sense. Somewhat similar are group tasks or collaborative tasks studied by, for example, Foster (2006) and Hansen and Järvelin (2005). Another task type is *support tasks*. They are often administrative tasks, and are characterised by not being in the central focus of the substance of the work; or, they can be otherwise "mechanical" (*cf.* Byström and Järvelin's (1995) automatic information-processing tasks). Support tasks have typically a well-specified process in principle, but of course it depends on the participant and whether she knows it or not. *Editing tasks* are semi-creative: something is commented on, edited, started, finished, or reviewed. A similar idea is present in Algon (1997), but not as a clearly self-standing and abstract main category. A task belongs to *intellectual tasks* if the participant describes it as a whole process: writing a text, making a decision, planning something. Typically these tasks require creativeness, consideration, time and productivity. Similar task categories are suggested by Algon (1997), Hackman (1968) and Li and Belkin (2008). Without doubt, some tasks were borderline cases. For example, if a task was described somewhat differently in the morning and in the afternoon, I had to carefully assess which aspects of the task seemed most important.

I wish to highlight two aspects about the task type classification. Firstly, it is based on the narratives of the participants. If they described a task as being to edit something, then I placed it into editing tasks. If they described a task as being to create something, and did not indicate incompleteness, I placed it into intellectual tasks. The idea was to see how their perceived view of the tasks affects task performance. I believe that they had reasons why a specific aspect of a task was stressed in task description and another was not. Many tasks include aspects of several task categories. It would be for another study to apply an "objective" task categorisation. In practice, it is clear that in categorising the tasks, I also used the information I had gained otherwise in the field (*i.e.*, in addition to the task labels), especially when a task label was unclear. However, the purpose was to follow the participants' subjective task descriptions as closely as possible.

Secondly, it is important to note that the task categorisation is not meant to value a task type over another. Task types are clusters of similar tasks and each cluster differs from other clusters. The clusters were only named afterwards, and though we selected as apt labels as possible, a single word cannot describe a task category and its differences to other tasks comprehensively. For example the label *intellectual task* (an alternative was *creative tasks*) does not indicate that other tasks can be performed without any intelligence, nor does the label *communication task* indicate that other tasks are performed in total isolation from other people.

Communication tasks were most common (32 % of all tasks) and support tasks least common (15 %) in Data Set B. Especially the exiguity of support tasks reflects the work roles of the participants in Data Set B; they were experts in mainly other fields than administration. Thus it is understandable that they did not perform support tasks frequently.

Work task types were found connected to task complexity. Support tasks are typically simple, editing tasks semi-simple, communication tasks semi-complex and intellectual tasks complex. Thus, task types form a potentially new perspective to task complexity. Note that though proved connected, task types and task complexity were judged totally independently.

Information resources. The participants used a variety of information resources during task performance. Observation and client-side logging methods were irreplaceable in showing the resources used in detail. The main categories were personal computer (PC), electronic organisational resources (information systems), Web resources, human and paper resources. These categories differ especially in their accessibility and potential flexibility or versatility. Our categories are similar to the ones found by Savolainen and Kari (2004, p. 422). Information resources are presented in detail in Papers I, III and VI. Please note that in this thesis, PC is a short label used for *local resources* (*local computer* as opposed to remote computer). PC as a resource category does not refer to the hardware as a whole (using any resources via computer).

In our data, work task complexity did not have a clear effect on the number of resources used in a single task. This is a somewhat unexpected result, since by definition it would seem clear that the more complex the task, the more information resources needed (especially in the sense of gaining knowledge from sources). Byström (1999) concludes from her data that increasing task complexity increases the number of information types needed which in turn indicates larger number of sources consulted.

I see some reasons for the absence of connection between the number of resources and task complexity. Firstly, it may be that the resources studied are typically multi-functional and thus several resources are not needed. Secondly, perceived task complexity is related to the amount of knowledge concerning the task. Perhaps in simpler tasks, a few resources are enough to satisfy information needs and create the possible end product. In complex tasks then, only a few resources are used because other ones are not known or understood to be of use.

Though the number of information resources stays quite stable, growing task complexity indicates a growing number of search tasks and queries. This suggests that people need more information in complex tasks which does not manifest in wider use of information resources (*cf.* Byström, 1999).

The number of unique search media (*i.e.* resources used by querying) varies more among task types than task complexity categories. Intellectual work tasks indicate a larger number of search tasks and unique search media than other task types. Thus, the number of search media seems to be connected to the degree of effort (such as creativity) needed instead of mere perceived complexity that can be affected by several factors (which, without a doubt, include the perceived intellectual effort, as well). Actually, intellectual tasks are the only task type where increasing task complexity increases the number of unique search media.

Search tasks. Overall, searching by querying was surprisingly infrequent. It was shown that only about 60 % of studied work tasks featured queries. This percentage was amazingly even in both data sets (59 % in Data Set A, 58 % in Data Set B). It would be an interesting future research question to find out the possible common factors of the non-query work tasks. In Paper I, we suggest that these work tasks may be either so simple (*i.e.* straightforward) that no new information is needed, or so complex (*i.e.* wide) that the information needed does not exist in retrievable form (such as when one needs to negotiate with colleagues). Data Set A was collected in a single organisation and it included more homogeneous tasks than Data Set B. Thus, it might be that the suggestions above may not hold for Data Set B. For example, Data Set B introduced a clearly instrumental type of information needs behind search tasks: over a fifth of search tasks were not meant to find new information but to perform an action in the information system in question. Thus, search tasks may be involved in work tasks without a ”real” *information* need. Work tasks without search tasks did not feature even these instrumental searches. Thus, query-based searching is rather rare in work task performance. Even rarer are search tasks that represent genuine information needs instead of instrumental ones that are performed not to find new information, but to just take a step forward in the task. One further suggestion for why query-based searching is not so common as might be expected, is of course that the information systems used provide the necessesary information without the participant having to form any queries. This would probably mean that the information resources used work well.

Problems in work task performance. In Paper I we analysed the problems encountered during task performance. Task complexity did not seem to affect the number of problems nor their type. Types of problems found were that organisation's information systems may respond slowly, there is misinformation, and local software does not work properly. These are evidently connected to the resources used rather than the tasks themselves. It is interesting that organisational systems cause most problems in complex tasks as well as in simpler ones though their use in complex tasks is relatively lower. Another interesting finding is that actually the performance of simple tasks suffers from careless mistakes. We concluded that in routine tasks, people do not concentrate as much as in more complex tasks. In complex tasks, concentration is a necessity by definition. On the other hand, it is possible that problems in complex tasks are only detected later, and thus not visible in the collected data. Of course, this is possible concerning simpler tasks as well, but problems in complex tasks may be more intricate and related to the task performance and substance at a deeper level which may make them harder to detect than surface-level problems, such as clear malfunctions of an information system. In practical data collection, it seemed that since we observers were not experts in municipal administration, most problems had to be noticed by the participant in order to be noticed by us as well. The deeper-level problems in question, the harder they are to be detected by an outsider during the flow of work task performance.

Kumpulainen and Järvelin (2012) conducted a thorough analysis on the problems (they call them barriers) their participants encountered when performing tasks in the field of molecular medicine. They found that the more complex the task performance session, the more problems per task (Kumpulainen & Järvelin, 2012).

However, it seems that overall the qualitative types of problems are similar both in research context (Kumpulainen & Järvelin, 2012) and in municipal context, though their frequencies may vary. These include technical problems due to both the systems themselves and limited user skills and missing or misleading information.

In Data Set B, information about the problems encountered was collected in the field, but the analysis was left for the future. However, the data suggest that problems encountered in Data Set B were common; and they were related to both the system use and the process of task performance. Perhaps some types of problems are implicitly visible in the number of search tasks in work tasks or in the number of queries in search tasks, variables analysed in Paper V.

4.2 Information needs in work tasks (RQ 2)

A generally accepted division of information needs or goals is between facts, known items and larger topics (Ingwersen & Järvelin, 2005, p. 291; Toms, 2011, p. 56). This seemed to work well in the present study, both when participants self reported their needs while using specific information resources (Data Set A) and when the needs were judged by the researcher based on motivations behind search tasks (Data Set B). In the case of Data Set B, an additional category, *instrumental needs* was added. This reflected the fact that some queries were not performed in order to directly find information but to navigate in an information system, for example. Similar categorisations are Broder's (2002) division between informational and other (transactional or navigational) queries; and Rose and Levinson's (2004) division between informational and other (resource or navigational) queries. Li and Belkin (2008) discuss informational (called *subject*) searching versus known item searching.

Real-life information needs are potentially evolving (Bates, 1989; Borlund, 2000; Blandford & Attfield, 2010; Hansen, 2011) meaning that searching may affect them, and the initial need may differ from the final information acquired. For example, Hansen (2011) reported that overall 23 % of studied tasks involved change in information need. Data Set A showed that the shares of dropped initial information needs are not connected to work task complexity. However, the more complex the task, the smaller the share of new facts and the larger the share of new topical information types. This indicates that in complex tasks, the information needs are harder to predict beforehand, since a large share (two thirds) of newly discovered information needs are broad in nature.

Needs for internal information (*internal* regarding the organisation in question) are more common than needs for external information, which is also shown in Sawyerr, Ebrahimi and Thibodeaux (2000, p. 106) and Babalhavaeji and Farhadpoor (2013). The dominance of internal information or resources is a noteworthy remark questioning the applicability of the findings of Web search engine studies to organisational work settings. Clearly the ratio of internal information depends on, for example, the work roles of the participants. Interestingly, our participants tended to overestimate the need for external information in simple tasks, and underestimate it in complex tasks. They also expected that they would use more external information in simple than in complex tasks, but the materialised use indicates the opposite. The expectations and actual use meet in semi-complex tasks.

Also Byström (1999) found that the use of external information is marginal. In her data, its share was however even smaller than in ours. We did not analyse externality of information by resource type, but Byström (1999) found that the use of internal people as sources grows, whereas the use of internal documentary sources decreases with increasing task complexity. Thus our findings are similar only when taking into consideration her documentary sources.

Overall information needs are sooner simple than complex. However, the share of broad information needs varied by Data Set. In Data Set A, information aggregates (Paper II; the participants' own descriptions of needs) formed over a third of materialised information needs but similar, topical information needs form only under a fifth in Data Set B. Still, also in Data Set A, information needs behind queries (Paper I; my own judgment of needs) were predominantly factual. Growing work task complexity indicates more complex information needs in Data Set A, but these two are independent in Data Set B. However, adding task type into analysis provides more information about this relationship. Growing work task complexity increases information need complexity in editing and intellectual tasks of Data Set B but decreases it in support tasks. In communication tasks, there is no connection between work task complexity and information need complexity.

In Data Set A, the participants estimated the accessibility and sufficiency of information found which were good overall, but both decreased with growing work task complexity. Factual information was considered easier to access and more sufficient than topical information; known items were between these two. Similarly in the study by Johnson, Rowley and Sbaffi (2016), participants estimated that the overall usefulness of the information found was higher in a more simple, closed search task than in a more open-ended one (*cf.* finding for facts *vs.* topical information).

4.3 Information resource use in work tasks (RQ 3)

Information needs are satisfied and information-intensive work tasks performed by exploiting various information resources. Information resource use is analysed in contributed Papers I, III, IV and VI. The methods varied between the papers. Findings in Paper I were based on direct observation, and in Paper III on questionnaire responses. These two complement each other, since some used resources may have been missed in observation and some in questionnaires. Possibly the questionnaire answers are a little value-laden (*e.g.* a useless or a quickly used resource left unmentioned). In Papers IV and VI, only log data are analysed which means that non-computer based resources are not present.

Physical information resources. In Data Set A, observation notes showed that in simple and semi-complex tasks, the most used and most important resources were actually not used on a computer at all; they were papers, books, hand-written notes *etc.* This is potentially caused by the organisation's and its workers' conventions. Most information was also available in electronic form, but the participants preferred tangible objects, such as print-outs when also an electronic file was available. Also the organisation's filing processes caused producing and handling print-outs.

Surprisingly, when the participants self listed their (re)sources, they did not mention needing or using physical resources almost at all. This cannot be caused (solely) by forgetting their use, since the questionnaires were responded to right after task performance. It is likely that the use was so habitual that the participants did not consider it as using a resource; this was perhaps a concept implicitly reserved for more special occasions, such as specially asking for advice from a colleague or accessing a database for the sole purpose of the task at hand. Another option is that papers were not considered as information resources because they were often duplicates; the information was available in an information system initially. However, the participants did use, for example, personal notes that were not available in another format.

Blandford and Attfield (2010, p. 15) and Serola (2009, pp. 84-86) discuss similar phenomena as discovered here: for some purposes, physical information objects are preferred though digital options exist. Lee (2003) studied information seeking by university professors. Her participants reported that though computer-based sources are favoured overall (rather than visiting a library) because of their easy access, found articles are often printed for quick retrieval for future needs (Lee, 2003).

PC use. In terms of time spent using a resource (Paper VI), PC has the largest absolute dwell times on average in all work task complexity categories. PC has the largest dwell times also in all work task types excluding communication tasks where communication media is used by far the most. PC use is often somewhat creative; however, reading, writing, editing and piecing together information typically intertwine. In the data, it was unlikely that a participant opened a blank document and started writing and finished the task without using other resources. Rather, information resources were used in an integrated way (*cf.* Kumpulainen, 2013, p. 44). Though local files on PC are inflexible as information sources in a sense, they are not just a random collection of information objects. For example, Kwasitsu (2004) showed that personal files belong to the top information sources for engineers.

The number of PC resources used does not change much with work task complexity (Paper I). However, PC resources become less important (importance is weighted usage frequency) when work task complexity increases (Paper I), but they are clearly used longer (Paper VI). These somewhat contradictory findings may be partly explained by the difference of the data sets. Data Set A includes mostly administrative tasks (decrease in importance of PC) whereas Data Set B features more diverse tasks (increase in time used in PC resources). PC resources may be especially important in creative tasks or in decisions that cannot be that well directly supported or performed by using organisational information systems or the Web, for instance. These situations include the need to create documents and consult more or less unofficial organisational documents (*i.e.* information not yet documented in an official database) created by colleagues (lists of candidates, summaries of statistics *etc.*). These types of tasks are likely to be more common in

Data Set B. This explanation is supported by the fact that in support tasks, relative PC dwell time drops with growing task complexity whereas in intellectual tasks it grows. Thus, PC resources have different roles that vary by task type; and task type dictates how work task complexity affects PC use. Overall, the data revealed that information resources in general have varying roles (*i.e.* a single resource can be used for different purposes and in different ways) which affect their popularity in work tasks. Detailed analysis of screen capture could possibly reveal more about these roles and ways of using PC resources.

Organisational information systems. In Paper III, instead of physical information resources, participants expected that they would use organisational information systems the most, and this was also most reported after the task. Organisational information systems can be able to support task performance to a limited extent. Both data sets suggest that organisational information systems are used less when work task complexity increases. This is especially the case in intellectual tasks which is understandable. Interestingly, Pearson's correlation shows that the use of organisational systems drops a little along growing task complexity also in support tasks though these tasks should be well supported by organisational information systems. In support tasks, organisational information systems take least time in the semi-complex tasks. Their place seems to be taken by communication resources. In complex support tasks, organisational resources are again used a great deal, but communication takes an even larger share of task performance.

The Web is an influential addition to today's information resources even at work, and it is exploited in many ways. In Paper I, Web resources were analysed under *Network sources* (*cf.* Savolainen, 2008, p. 283) with shared files and intranet. In later papers, the Web was a category of its own. In any case, network or Web resources take a step towards (potentially) more heterogeneous information environment that can be at least tried when organisational systems do not seem appropriate sources of information. In Paper I, network resources were shown to grow in importance and in use with task complexity. The connection was not linear when participants self reported their resources. However, a third of dropped resources were Web resources in simple taks, whereas there were no dropped Web resources in complex tasks. In actual fact, a quarter of unexpected resources were Web resources in complex tasks. These findings support the interpretation of complex tasks entailing perhaps more vague information needs that cannot be fulfilled by using only ”official” resources available.

The Web is often exploited by using general search engines or issuing queries within a website. Choo, Detlor and Turnbull (2000) found that a half of Web episodes in knowledge work include active information searching by querying. Slone (2004) studied library users' Web searching behaviour and found that in 42 % of the sessions, (general) search engines were used. Overall, querying was used in about 80 % of the sessions analysed. Other types of searching in Slone's (2004) study were following links and writing direct URLs. The information needs of the library users were more likely to be query-prone in the first place compared to Web use in work: Slone (2004) approached library users who were intending to use the library's online catalogue and asked them to participate. Thus, these participants likely had a quite well-specified information need in mind.

The contributed Paper IV shows that the Web is the main search medium in a third of all search tasks. The relative use of main search media does not change remarkably with work task complexity. However, the effects of work task type on main search media are clearer. The Web is searched the least in communication tasks (where communication media is used most), and above the average in intellectual tasks. In intellectual tasks, the Web was often used for finding inspiration and material for producing new information objects, such as slide shows. Nevertheless, the Web is the main search medium even more often in support tasks. Thus, the Web as search medium differs from Data Set A where the Web featured only under a fourth of all queries. Paper VI suggests that the time spent in search engines – but not in other types of websites – increases with work task complexity. In intellectual tasks, the time used in search engines is larger than in other task types, but other websites are used less. This may indicate that searching has not led to successful results as easily as in other task types.

Communication. Earlier research shows that human sources are much used and even that work task complexity increases their use as shown by Hertzum's review (2014, p. 780). However, this varies in individual studies. For example Sawyerr *et al.*'s (2000) survey in firms showed no difference between the frequency of use of *personal* and *impersonal* (such as documents) information sources. Babalhavaeji and Farhadpoor (2013) found that university managers' use of personal sources clearly exceeds impersonal sources. Both these studies discussed environmental scanning as the context for source use.

Both our data sets covered the use of email and instant messaging whose importance in work has been discussed for example in Ou and Davison's study (2016). In Data Set A, face-to-face communication was included but it was not visible in the logs analysed in Data Set B. In direct observation reported in Paper I, communication was seen to increase with work task complexity - both the number of resources consulted as well as their importance grew. In complex tasks, communication resources became the most used and most important, probably because they are flexible and carry tacit knowledge. Paper III shows that also the participants' expectations regarding the frequency of human source use increased moderately with work task complexity, and overall human sources had large shares of unexpected ones. Materialised use reported by the participants showed instead a curvilinear connection between human source use and task complexity: human source use reached its peak in semi-complex tasks.

Thus, the trend seen in observation did not manifest in the participant's own lists of information resources they had used. It is possible that information resource use outside observation affected this (a task could last longer than the related observation session). It is also likely that the participants listed their resources differently than the observer. I analysed whether they used the telephone or email or not. The participants specified their sources in more detail (such as they are going to send an email first to person X, then to person Y), and on the other hand they may have been selective in listing (*e.g.* a quick question to a colleague omitted).

Data Set B also suggests that communication is not something that self-evidently increases with growing task complexity. Measured as time spent in communication resources (mainly email and instant messaging software), communication increases only in support tasks, and the increasing trend is clear. On the other hand, in intellectual tasks that could be demanding and complex overall by definition, the use of communication resources actually drops a little though not statistically significantly with work task complexity. These findings further confuse the interpretation of communication resource use. Support tasks should be routine-like or well-specified in a sense, but perhaps that is exactly the reason why increasing complexity increases human consultation in them. Especially administrative tasks often have ready resources, which must be used and which may not be that familiar to the participants. On the other hand, the intellectual tasks found in the data were often at the core of the expertise of the participant in question. Thus collaboration or colleagues' help may be of minor importance, especially if increasing complexity indicates self-contained cogitation and information production. It is however possible that Data Set B is skewed in this respect because it does not include face-to-face communication.

Search media refer to the resources that are used by querying**.** It was found that PC directory is seldom the main search medium, but other search media (organisational resources, the Web and communication resources) share the rest almost evenly (Data Set B). This is interesting because it indicates that these three are used in a similar manner; in other words, it is not only the Web that is searched by querying. As PC was used a lot in terms of time but searched by querying only little, search engines indicate the opposite. Their use is really low in terms of time spent formulating the queries and reading the results lists. This time is however pure and effective searching time since search engines can hardly be used in other ways. In Data Set A, search media use was not even. Clearly the largest share of queries was issued in organisational resources (74 % if intranet included), a quarter to the Web, and two queries to email. The low number of email queries is especially interesting. Human sources were utilised in almost all tasks in Data Set A, and most often communication was managed via email. In addition to simply sending and receiving mail, email was used as repository of information. The participants must have had quite sophisticated ways of organising their emails since they seemed to know where to find information without querying; at least browsing was considered a better option.

The changes of main search media are small between work task complexity categories (Paper IV). Among work task types, the Web is the most popular main search medium except in communication tasks, where communication resources are more popular. Within task types, the Web is most prone to changes of use as main search medium when work task complexity increases: its use decreases in other task types but increases in intellectual tasks.

Search task performance processes were analysed in Paper IV. These processes were: a) *single*, if there was only one query in a search task; b) *list* if the search task formed of a sequence of rather technically related queries; c) *stable* if queries were forming a content-wise whole but affected little each other; and d) *developing* if queries were building to each other or the information found during the search task. The inspiration for these process types has been gained from Kumpulainen (2014, pp. 865-867) though the classification is totally adapted to suit the present study.

Single search processes dominate the present data, forming over half of search tasks. Also Kumpulainen (2014) found that single processes were the most common. In our data, search processes are only weakly connected to work task complexity. Cautiously interpreted, processes become a little more complex with task complexity: the share of developing processes increases from semi-simple work tasks to semi-complex and further to complex ones, and the share of single processes drops. However, in the most simple work tasks, developing processes are nearly as common as in the most complex tasks. The complexity of information searching does not directly relate to the complexity of work task; their connection is more complicated. This is easily missed in user experiments. Kumpulainen's (2014) findings show that in routine tasks (simple tasks) searching is actually more complex than in semi-complex tasks, but complex tasks differ clearly from other task types, since, as a rule, searching is explorative in them. Our findings are similar.

Within our work task types, intellectual tasks differ from other tasks because in them even a fourth of search tasks have a developing process and only above a third of processes are single. Interestingly, list processes also form a fourth of search tasks in intellectual work tasks. Support tasks resemble intellectual tasks, because in them, search tasks are quite often (over a fifth) developing, and single processes are rarer than in communication or editing tasks. Thus, work tasks may be connected to searching, but one-to-one connection cannot be expected. It is not self-evident, for example, that a work task that should, by definition, have well-specified performance process, would include only well-specified search tasks, as well.

Information resource use and information needs. Paper IV showed that information need complexity and search process complexity are positively correlated. To some extent, information needs and information resource types are also connected, as analysed in Paper III. Before task performance, the participants reported getting mainly known items from organisational information systems, whereas email, other human sources and the Web were used for finding topical information. In materialised use, the participants' reports considering email use changed from information aggregates to known items which indicates that actually a single mail or file was enough to satisfy an initially topical information need.

4.4 Queries in work tasks (RQ 4)

I analysed queries regarding their number and importance in work tasks (Data Set A); and their number in search tasks, their length (number of search keys) and type (Data Set B). The majority of search tasks included only one query with one search key. Earlier studies analysing real-life log data support the interpretation that searching is "simple" (Silvestri, 2010, p. 31, 35; Jansen & Spink, 2006, pp. 255-256). Using assigned search tasks in user experiments may be disorienting in this respect. For example, Wu and Cai (2016) analysed adolescents' Web searching using three, rather typical assigned search tasks. They found that there were over 5 queries per search task, and typically queries were long and even forming full sentences (Wu & Cai, 2016).

Excluding the issues of age that were in the focus in Wu and Cai's (2016) study, it may still tell something important about the differences between real-life and experimental searching. Also Aula *et al.* (2010) found in their experiment that on average, there are 7 queries per search task and each query has on average 5 query terms. Rather multi-query search tasks and long queries in experimental settings have also been reported by Li and Hu (2013). In experiments, assigned search tasks are externally given, concrete snippets of text. Thus, the *information need* is already in textual, exact form and it can be returned to when searching for the right answer. Furthermore, the search task exists in its own right, that is, it does not serve any other purposes than stimulating searching. Thus, the search task itself gets all the attention, and the assignment gives static understanding of what it is about. This is quite the opposite of what was found in the present study (however, please note that we analysed search tasks outside the Web, as well). As search tasks and information needs form intrinsically and quickly, they exist only in the head of the searcher. The immediate reaction is to spell a word or two in a search box and try out what can be found. It is likely that the participants have learnt that short queries work well enough. It is important to remember, that if the search task fails, there exist other ways to proceed in the work task the search task was intended to serve in the first place. The goal is not to succeed in the search task but in the work task. These issues may affect that searching for its own right (experiments) is more complex than searching as a part of larger goals.

Though queries occurred rather infrequently in our data, they seemed to have an important role in work task performance (analysed in Data Set A). Forming a query is typically only one option to proceed in the work task; and choosing this option may indicate that it is considered the best option available. However, the searching itself was seldom the main interest in a work task or a search task. The latter means that even search tasks mainly served other purposes than actual information gathering; the point was to move forward in the work task.

The number of queries and search keys. Both datasets showed a slight increase in the number of queries when perceived work task complexity increases. However, as analysed in Data Set B, query length decreases at the same time. It may be that specific (longer) queries are easier to form in simple tasks, or that the information systems used in simpler tasks encourage issuing longer queries.

In intellectual tasks, there are more queries per search task on average than in other work task types. Queries are shortest in communication tasks. This may partly be explained by the fact that in communication tasks, communication software were used as the main search medium most often, and typical queries in email and especially in instant messaging software are names (normally either first name or last name only).

Within work task types, query lengths decrease clearly with work task complexity in support and editing tasks, whereas the overall trend of increasing number of queries is not actually visible in any of the work task types. However, there is a positive but not statistically significant correlation between the number of queries in search tasks and work task complexity in support tasks. Kim (2006) found that perceived search task difficulty is connected to an increasing number of query reformulations in both factual and exploratory search tasks, which corresponds to the overall tendency of our data. I did not analyse perceived search task difficulty but it is likely to be affected by similar factors as perceived work task complexity.

Wu and Cai (2016) found that closed search tasks (finding the correct answer) feature more queries, and queries are also longer than in other types of search tasks (open-ended and research-oriented). Though not totally analogous, closed search tasks are by definition similar to our simple or support work tasks, and factual information needs. Thus, well-specified tasks seem to entail longer queries, and though search tasks in intellectual and complex work tasks in our data include more queries than other work tasks, simple or support tasks come rather close. Thus, Wu and Cai's (2016) findings are to some extent similar to ours. Borlund (2016) found that teachers' *muddled topical* (simulated) work task included more search terms and more search iterations than a closed one. This is in contradiction to Wu and Cai's (2016) findings, but follows our findings in terms of increasing number of queries.

Expertise can be considered having an inverse relationship to work task complexity - expertise in a subject matter is likely to decrease task complexity. Palotti *et al.* (2016) found that experts use more search terms per query than lay people when searching for medical information, which in general terms follows our findings. However, they also found that experts' search sessions include more queries. This is in conflict with our findings. Without doubt expertise is only one factor affecting especially *perceived* work task complexity, and thus findings based on these two different measures should be compared with caution.

Query types. Four query types were found and analysed in Data Set B. They were figure-only queries (called f), queries formed of pre-defined values (v), and natural language queries with or without proper names (p, proper name; c, common noun). Queries were typically quite specific since only a third of search tasks featured natural language queries without proper names (type c). P-queries were most common overall. However, they were most common in communication tasks, probably because in communication tasks, communication resources are used as the main search medium most often, and queries to communication resources are often names. Query types do not react clearly to task complexity. However, search tasks with p-queries are rarer in the most complex than in other tasks. This may indicate that forming exact queries in complex tasks is more difficult. A similar trend is seen in intellectual tasks compared to other task types. Further, growing work task complexity tends to increase the number of query types in search tasks. This holds also particularly for intellectual tasks.

Vakkari *et al.* (2003) found that search terms become more specific when participants gain more subject knowledge. This is in line with our findings, since subject knowledge can be considered as having an inverse relation to task complexity: The less knowledge about the subject matter of the work task, the higher the perceived complexity is likely to be.

In summary, most queries contain only one search key; perhaps information systems could better support these queries by providing subject facets for browsing the results, for instance. On the other hand, it is possible that people use short queries just because they have noticed that they work well. In the present data, short queries can as well be exact: they represent for example product codes as search keys in internal databases.

A typical search task includes queries with proper names. This calls for special support in handling proper names in search, just as recognising different spellings, providing autocompletion options or query suggestions. In complex work tasks, search tasks with common noun queries are not unusual, and queries are typically shorter than in less complex work tasks. Thus the performance of complex work tasks may benefit from supporting the learning of the searcher so that the query can become more precise. Query suggestions, providing alternative facets in results and implicit relevance feedback can help the searcher to focus her information need and understand the subject of the search better. Supporting search tasks and work tasks in information (retrieval) systems calls for modelling the tasks of searchers, tracing what they are doing, *i.e.* understanding what their goal is in performing the query, the search task, and even the work task.

Commercial Web search engines may already work well in such search aids as suggesting queries, autocompletion, and correcting spelling mistakes. Organisations may benefit from investing in internal search of their own databases and intranet as well. Easily findable information can streamline knowledge work by saving both time and effort of task performers.

5 Discussion

First, the discussion section briefly deals with the most important and interesting empirical findings and observations made about real-life information searching as an object of study. I make some statements that are marked in bold and explain them further. This is followed by sections on limitations of the study and implications for future research.

5.1 Information searching in work task context

In information searching research, there is a quest for a unified theory of task-based information searching. Overall, my findings support Leckie *et al.*'s (1996) model where tasks affect information needs and further information sources. Byström and Järvelin model (1995) presents more detailed factors affecting information searching than Leckie *et al.*'s model (1996), such as the idea of subjective work task, personal and organisational factors. I have concentrated on only task features but followed Byström and Järvelin's (1995) conception of subjective work task. Further, Pharo (2004) and Vakkari (2001) have presented detailed models of interconnections between IR and larger tasks. My empirical findings support the basic ideas behind these models but also suggest that when naturalistic field study method is applied, the connections between phenomena prove even more complicated.

The nature of work tasks affect information searching but the connections are not straightforward. For example, a complex work task does not necessarily indicate complex search tasks. Even if the differences between work task categories are sometimes small, especially the most complex work tasks and intellectual work tasks may stand out from others. Further, the effects of work task complexity are mediated by work task type; that is, the effects of work task complexity differ between work task type categories.

As both work task complexity and work task type were defined based on direct information given by the participants, it can be concluded that the participants' own experience affect task performance. Thus, it is worthwhile studying concrete task processes (in addition to tasks as more abstract work duties) and perceived task complexity (in addition to so called objective task complexity).

The ways the participants described their work tasks (task labels) is really similar to what Czerwinski, Horvitz and Wilhite (2004, p. 177) discovered, both in terms of content (wordings, things mentioned) and of level of granularity. This is promising: perhaps task types applied here are more universally applicable and beneficial in future research, since they were found to affect information searching.

I wonder what could have been a measure of *objective complexity* in my data: would using that kind of measure (or *work duties* instead of task processes) have changed the findings? It is not clear what objective complexity even means in real-life task performance where the performer is always present with her feelings, experiences, skills, knowledge *etc*. Defining objective complexity in terms of complex performance (that can be calculated in advance in studies where assigned tasks are used) may lead to circular reasoning where findings always show that searching is complex if the larger task is complex.

Information searching within a single work task or search task may be simple but the variation between tasks is large making real-life searching a complex phenomenon as a whole. People use a wide range of information resources in many ways in their work. Resources may be used in an integrated way, or when necessary, one optimum or perhaps the only suitable resource is selected. Also the ways of use are integrated. Searching for information interleaves with modifying, producing, applying and adopting information; task performance is about task-based information interaction as presented by Järvelin *et al.* (2015).

Though often interesting from the search engine and IR point of view, and despite its apparent popularity, *the Web* is far from being the only search medium in work-related information searching. In the present data, queries were issued in organisational information systems, local directory and software, and communication resources as well. This may indicate that findings of server-side log analyses about Web searching may be of limited applicability considering task-based information searching in knowledge work.

Search tasks in the studied environments were formed spontaneously, in order to directly solve a problem or otherwise proceed in the work task. Searching was seldom planned beforehand (*cf.* Pharo & Järvelin (2006)). This may indicate limited applicability of findings from studies that use search-centred assigned tasks that even provide the searcher with a ready, stable description of relevance. In the work tasks studied here, there were no assignments the participants could return to when assessing relevance of found information objects.

The information needs, and thus the search tasks and relevance criteria were flexible and internally generated. The dynamic or iterative nature of authentic searching is widely recognised in literature (Jansen & Rieh, 2010, pp. 1525-1526) and there is a need to support this nature better and better in information system design (Marchionini, 2006).

5.2 Studying information searching in authentic environments

Field studies using several data collection and analysis methods are vital in order to understand real-life searching. Direct observation is a valuable method even when collected only part-time, as a support for understanding other types of data. Also other real-time data collection methods (logs, screen capture) are indispensable in providing data on actual task-based searching or wider task-based information interaction. This cannot be achieved through analysing only questionnaire and interview responses that are based on narratives of task performance. Further, it proved feasible and beneficial to include both qualitative and quantitative analysis methods in the same study. These two are not conflicting but belong to the same continuum of analysis methods.

Any kinds of knowledge work tasks are potentially interesting for information searching studies. There are no (knowledge) work tasks that could be considered nondescript: any task can yield information searching. Information searching is present also in work tasks that are not about collecting information *per se*, that is, when the task is about other information related activities. Search-focused user studies can reveal how people search in situations where they have an externally generated assignment with information about what to search for. If we instead want to support the context of searching, the work, these types of studies are insufficient since they focus on a subset of search situations. We need to include other types of work tasks beside students' rather complex writing tasks that include explicit phases of information gathering. Since there are conscious efforts to design more *task-aware* information systems (Kelly, Arguello & Capra, 2013, p. 117), findings from the field seem to suggest that the focus should not be only in tasks that are search-intensive by nature.

5.3 Limitations

This thesis is based on authentic data collected in the field, which causes some limitations. First of all, the data set was mainly collected by myself and the analysis was designed and conducted totally by myself, though assisted by discussions with coauthors and other colleagues. Thus the data and analysis may represent a view that would differ from the views of other researchers if they had been present in the field. Also the analysis methods are limited to my knowledge, skills and creativeness.

Second, the data were noisy and sparse to some extent. Everything could not be controlled. People multi-task, work tasks do not come in neat, ready packages to be analysed; sometimes participants forgot to start the screen capture; or technical problems occurred. These limitations were overcome with even harder detective work. In the case of laboratory study, the researchers would have accepted only the perfect instances of data. In the present situation, it was considered, however, that the more the data, the better. The results – as they are to reflect the real-life searching - would have been more biased if the data inclusion threshold had been too high. The data set consisted of several and longitudinal data types that supported each other (*triangulation*) which made it possible to analyse the data even when they were not perfect. So far, Data Set B was analysed only in terms of computer-based information resources. This was only a question of research priorities. Field notes from direct observation include detailed information about the use of other information resources as well, similarly to the field notes of Data Set A. Further, the participants in Data Set B as well, listed their information resources related to each task in morning and afternoon questionnaires. These data are ready for future analysis.

Third, this study could not avoid the obvious problems common to most similar studies. The data set is relatively small compared to typical server-side log studies or large surveys; and it is collected in a specific time and place. However, as a qualitative real-life data set, the amount of data is considerable. The set of participants was not based on any statistical sampling method. This may cause some bias that is hard to predict. It is possible that the participants were a little more extrovert than average because they knew that the study would include quite intense interaction with the researchers, and the participants had to be comfortable with showing their work in detail to a stranger. Furthermore, it is possible that the busiest people did not participate, nor the ones that felt that they were working with too confidential information to be exposed to even this kind of study. It is also evident that the organisations studied had to be favorable to research.

Despite these limitations, I have no reason to believe that the studied work tasks were somehow "exceptional". On the contrary, based on discussions with the participants and observations in the field, tasks seemed to be quite representative. The participants sometimes reported that being an object of observation felt strange, but they also reported that they were working quite normally, perhaps a little more effectively under the pressure of being observed. In any case, they were observed in their totally normal working surroundings and they had their duties to be fulfilled. Thus it seems likely that the data reflect their ordinary work days.

5.4 Implications for future research

This study contributed to the knowledge of real-life information searching. The several time-consuming and thus seldom used data collection and analysis methods provided an in-depth view on searching. One of the key factors of success when exploring real life is using several methods that show different sides of the studied phenomena, thus giving a larger picture. We collected information that was directly provided by the participants themselves about the work tasks (*e.g.* task complexity) but also formed our own understanding of the work tasks (*e.g.* task types). In Data Set A, we observed all work tasks included in the data and did not have a transaction log in use. Observations were fewer in the Data Set B, but work task types and complexity were connected to information searching that was logged in addition to direct observation, and the picture was even further clarified by interviews. The research community can benefit from the insights gained during the data collection and analysis, and the results can be further exploited when designing new field studies or more realistic user studies.

The results raised questions of whether typical assigned search tasks are actually too complex and intellectually demanding to represent all kinds of search tasks; and whether assigned tasks are too focused on maximising the quantity of searching (often in minimal time) as searching is actually more often only a part of a work task. Considering these aspects may ensure more valid and usable results of user tests.

Information search actions seem to be utterly tightly connected and integrated in the work tasks. Work tasks are a flow (whether a bumpy or a smooth one) where information needs pop up and participants react to them immediately, applying different methods depending on the situation. Future simulated work tasks or assigned search tasks could possibly be more problem-focused. It means that the participants are given a task assignment to perform that is beyond only explicitly finding something. If designed carefully enough, the assigned task may still lead the participant to extensive searching but the information need formed in the mind of the participant is more realistic. Without a doubt, there are resource-related difficulties in forming these kinds of tasks but at least the present real-life data is filled with situations where the participants need to search though the work task is not about searching for information in the first place.

This leads to an interesting future question: Why did the participants choose to express their information needs as a query in an information system instead of other possibilities available in the situation? Or vice versa, why they did not? Considering the design of IR systems this is crucial. It is likely that the participants acted according to the principle of the least effort (Zipf, 1949; Mann, 1993, pp. 91-101). They chose the expected "easiest" way to find the information. Without a doubt this entails the idea that the information must be *sufficiently* high-quality at the same time, not just easily findable. Prabha *et al.* (2007) discuss the criteria searchers use to decide when they have enough information.

Another related, interesting question is: Where did the search keys come from? I did not conduct any deep-level analysis of why each search key was chosen. However, the data of the present thesis touched on the question as they included qualitative contextual information, which supported the analysis of information needs, search processes, and the role of searching. The origin of queries is not readily visible in a mere search engine's anonymous log. Interpreting the query correctly means understanding the user's goal better, which further means assisting the user better in reaching the goal. For example, it is not obvious that searching for a university's name means that the searcher wants to find its website and then her information need is totally satisfied. This may be one step in the process of reaching the goal but it is likely that the searcher has a larger goal in mind, as well. Perhaps the name of the university is the only clue she has, so she tries it first. Ingwersen and Järvelin (2005, p. 356) call these *access handles*. If state-of-the-art search engines support finding relevant documents well based on one query (*i.e.* they support one-step goals), how could they support also the goals of a whole, longer search task – not to mention the work task itself? These types of questions are analysed in task-based IR by, for example, Emine Yilmaz (*e.g.* 2016). Interestingly, a workshop paper by Gäde *et al.* (2015) suggests that real-life search tasks are often complex, and performing complex search tasks should be better supported. It is true that typical search engines best support simple search tasks; however, search tasks were actually rather simple in my data. Perhaps it is the larger, underlying tasks that should be better understood, so that even seemingly simple searching could be supported. This is what Toms (2015) also calls for. Again, complex real-life tasks are typically not only about querying but performing the task typically in multiple steps and using multiple resources (Toms, 2015).

The present study was explorative in nature and focused on the empirical part. However, the results can also be further developed to support forming a unified theory of task-based information searching (or *access* or *interaction*). Our findings provided some views on how work task complexity and type can be connected to various features of searching. Searching could also be connected to a wider context of task process as suggested by Järvelin *et al.* (2015).

Though organisation type was not considered as an explicit independent factor in the study, the findings suggest that studying only one organisation (not to mention studying only university students of information science or similar) may lead to results that are not generalisable enough to other environments. The homogeneity of the participants is often considered an advantage, and this may lead to a fallacy that a homogenous group studied can actually represent any other homogeneous group, as well. (See more discussion in Section 3.1.)

Clearly, this kind of data set as presented here can answer several questions but it also suggests new ones. For example, we were not able to find a linear connection between work task complexity and search task complexity, though these are sometimes considered as being in a close relation. Perhaps the connection is curvilinear or indirect. This point should be further analysed. Also it would be beneficial to move from work task context to even working day context, and to analyse how work performance is affected by task switching. This is left for future research. Data Set B could be exploited in the analysis of work task or information resource switching, and non-computer-based information resources, for instance. The rich data could be also further analysed qualitatively, finding for example how query keys were selected as suggested above.

Similar studies to the present one should be conducted in the future despite their demands on researchers and resources. These studies could especially benefit from the input of a larger research group (as proposed by Vakkari (2003) and Kuhlthau (2005)) than I was able to collaborate with. At its best, such collaboration may lead to a whole round of research: First, researchers set hypotheses based on earlier theories or models; then data are collected from the field in order to test them. Or, the empirical phase may be explorative in a new environment followed by hypothesis formation and further testing in more controlled study settings. The researchers specialised in designing IR systems can then build prototypes of features or systems that can be tested in a laboratory and thereafter with (real) users. Without a doubt, all this calls for resources and collaboration with several researchers. However, the information searching research community can benefit from collaboration that does not see the researchers ”other side of the fence” as an adversary but rather as potential partners whose findings are forming the same path towards understanding the phenomenon and designing systems that better support task performance.

6 Conclusions

This dissertation discussed how work tasks affect information searching, and for this, field study methods were applied. It was stated that information searching has been studied using a range of approaches earlier, but knowledge about authentic searching in context is still too scarce, forming a clear need for the present study.

The data analysed consisted of two independent data sets with a total of 28 participants from seven organisations. Data collection methods included interviews, direct observation, questionnaires, transaction log data and a screen capture video, which were analysed both qualitatively and quantitatively. It was found that work task complexity and work task type affect information searching; information needs are overall rather simple; people use a wide range of approaches and information resources to satisfy their information needs; and that queries and search tasks are typically really simple.

Work tasks are an important context for searching, and they should be taken into account also in more controlled settings than field studies. Though the present study could not avoid having some limitations in implementation, it was able to reach its goals and contribute to the research community's knowledge about real-life information searching and possible methods for studying it.

This was an empirical study that was, however, able to contribute to the following aspects as well:

- Methodological knowledge: It proved that using several data collection methods in the field is beneficial; especially the combination of automatic logging and qualitative direct observation.
- Design of IIR experiments: The findings suggest that in realistic IIR experiments, assigned search tasks should be better integrated into larger tasks or problem solving beyond providing obvious information needs for the searchers.
- Theory formation: The study suggested an abstract task type classification that mediates the effects of task complexity. The empirical findings suggested various connections between work tasks and information searching to be further studied both in new field studies and in more controlled settings.

7 References

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Task Complexity and Information Searching in Administrative Tasks Revisited

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ABSTRACT

In task-based information searching, the task at hand is a central factor affecting information search. Task complexity, in particular, has been discovered to affect searching. In the present study, we shadowed the tasks of seven people working in city administration. The data consist of shadowing field notes, voice recordings, photographs and forms. We study, how task complexity affects information searching and information resource use. Task complexity was defined through the task performer's own experience (perceived task complexity) and her estimates of her *a priori* knowledge concerning the task. We analyzed the data both qualitatively and quantitatively, focusing on the links between task complexity and the use of information resources, information searching and problems encountered. We found that task complexity has a central but ambiguous relationship to task performance. The clearest differences were found between simple and complex tasks. In addition, perceived task complexity seems to affect the ways of performing the task more than *a priori* knowledge. The more complex a task is perceived, the more searches are performed and the more they concentrate on networked resources instead of information systems provided by the organization (SPOs). The use of resources on the task performer's PC and the SPOs decreases when complexity increases. In proportion, the use of networked resources and communication resources increases. The total number of information resources used is somewhat greater in complex and semi-complex tasks than in simple tasks; and each resource is used for a longer time on average. Our study shows that task context and especially task complexity seems to affect information searching and the selection of sources.

Categories and Subject Descriptors

H.3.2 [**Information Search and Searching**]: Search process

General Terms

Human Factors.

Keywords

Task-based information searching.

1. INTRODUCTION

The analysis of task-based information searching aims to understand a person's (a task performer's) current task and its desired outcome, and how this may provide useful context for the information searching processes. The latter can be seen as a means to aid in the accomplishment of a purposeful action, the work task [14] [32]. Vakkari [33] and Toms [31] have written useful reviews of task-based information searching and analyze broadly tasks as the context of information seeking and searching. Byström and Hansen [6], and Li and Belkin [22] conceptualize tasks.

Several studies have analyzed task-based searching empirically. Sometimes, however, tasks are seen as search tasks or information seeking tasks [15] [23]. This leaves the relationships of resources and work tasks open. Others define tasks as the goals of information-seeking behavior [12] [16] [25], but do not study work task *processes*. Some studies have focused on a specific work task process as the context of information searching [2]. Yet others have chosen abstract task classes [29] rather than real life task performance as the context of information searching.

The present study focuses on information searching in real tasks in public administration performed by real people in their regular working environment. A similar approach has been followed by, e.g., Vakkari, Pennanen and Serola [34], Kumpulainen and Järvelin [19], Byström and Strindberg [8] and Hansen and Järvelin [13]. By observing searching during work task performance, one learns which information systems are used, how they are used, and what barriers the users encounter.

The present study was inspired by Byström's thesis [5] (see also [7]), which studied the relationships of task complexity, information seeking and the use of information resources in public administration context (among other contexts). The same public administration organization is studied, real task performance with its associated information searching is observed, and information resources mapped in the present paper. The overall research question is, how does task complexity affect information searching and the use of information resources in the city administration domain?

Our study is a case study based on longitudinal observation of 6 city administrators in the City of Tampere. The subjects were selected internally in the city administration. They were shadowed over a period of 3 months. For each subject, there is a filled-out orientation questionnaire. The main data set represents 59 work task processes that were shadowed by 2 researchers. For each task, there is a pair of task initiation forms and task ending forms, shadowing field notes and voice recordings taken with a smart memo pen, and photographic tracking records taken with automatic camera carried by the shadowees. While information searching in digital resources was of particular interest, the city did not allow installation of any logging software or video recordings.

Because the same organization is studied, there is a possibility to compare, indirectly and at a high level, task-based information searching in Mid-90's [5] and in 2011. This is of interest since digitalization and process control were only beginning in public administration in the 1990's and the modern work environments are digital in many aspects. How does this affect information searching and the resources used?

The paper is organized as follows. Section 2 reviews relevant previous research and Section 3 explains the design of the present study – research questions, data collection and analysis. Findings are reported in Section 4, followed by discussion and conclusion in Sections 5 and 6.

2. PREVIOUS RESEARCH

On a general level, a *task* is the collection of activities striving for a goal, an outcome [33]. Work tasks are defined by the duties towards the employer and they may include information seeking tasks that further include information searching tasks. According to Byström and Hansen [6] a task can be a task description or a task process. The task can be seen as objective or subjective but, to some extent, task performance is always affected by the characteristics and interpretation of the task performer. The tasks studied in a piece of research may be either authentic or simulated. The simulated tasks differ from the authentic real-life work tasks in that they can be systematically varied and several variables can be controlled [6]. Vakkari [33], among others, has studied broadly tasks as the context of information seeking and searching. Tasks are conceptualized by Byström and Hansen [6] and Li and Belkin [22].

One of the problems of the concept of task is its varying amplitude: in Borlund's thesis [4] the term *work task* is used as a synonym for a simulated information retrieval task including a short cover story whereas in Byström's thesis [5] the term *task* is used for authentic decision tasks performed in a city administration context, to mention a few. In the current study, the tasks are authentic work tasks as defined in Byström and Hansen's [6] categorization. These tasks exist objectively as work duties but the ways to perform them and their complexity are defined by the task performer. The work tasks include both information seeking and information searching activities, which overlap in authentic situations.

In his book Choo [10, pp. 236-237] discusses the multiple roles managers have in decision making that affect information seeking. The sets of roles are interpersonal, informational, or decisional roles. Three informational roles, for example, are the monitor (seeking information about the organization), disseminator (transmitting special information into the organization), and spokesman (disseminating organization's information out to the environment). In the present paper, the idea of a task is narrower than his conception of a role. Further, we have studied administrative workers in other positions than managers as well.

Task complexity can be defined in many different ways. According to Campbell [9], the perceptions can be divided in three groups: in research, task complexity is either viewed as something following from the characteristics of the task performer or the objective characteristics of the task itself, or both. Timmermans [30] studied the influence of task complexity on information use in decision making when the task is to elect a suitable employee. Task complexity was modified by varying the number of applicants and their known attributes in the experiment. Byström and Järvelin [7] separate tasks in five groups according to the task performer's ability to define the task process, the outcome and the information needed in advance. Kumpulainen and Järvelin [19] use the definition of *a priori* knowledge in relation to task session complexity. Li and Belkin [22], instead, regard *a priori* knowledge as neither a part of task complexity nor task difficulty. In their classification [22], complexity may be objective or subjective but difficulty is only a subjective dimension. Task complexity can also come from the task's nature. Byström and Strindberg [8] split up work tasks in just two groups, routine tasks and creative tasks.

Kumpulainen and Järvelin [19] used the term *resource* to describe all the information sources, information channels and other requisites for handling information. We use the term *information resource* similarly. The term is especially necessary when delineating the empirical data: In the real world, all the information resources needed do not directly provide information or access to it. These include e.g. the tools to generate information such as word processors, or information systems for editing and relaying information.

Different kinds of *problems* in information seeking and searching have been studied widely. Some have concentrated on a few types of problems, or barriers, like time [26] or information overload [1]. Problems in using a certain search system are expressed as problems with search key formulation, lacking skills, lacking domain knowledge [35] [36] or the search topic [17]. Kumpulainen and Järvelin [20] had a task-based approach to studying barriers to information searching during task process. Similarly, in the present research all such situations in which the task process is hindered, slowed down or even stopped are seen as problems.

Byström [5] studied broadly the relationships between task, information and sources. She concluded that people tend to use other people as information sources and channels when tasks are complex or several information types are needed. Task complexity is related to the amount of information types needed. Byström found that as complexity increases people prefer using experts as information sources [5]. According to Serola [27][28], the share of human information sources (including colleagues, experts and meetings) was only a fifth of all information sources used. Individual people were mostly used in seeking problem solving information, group meetings in seeking information about domain specific concepts and their relationships.

The more complex the task and the more different information types needed, the more information sources are used [5]. A similar phenomenon was observed by Kumpulainen and Järvelin [19]: A complex task session involves a broad range of information sources from Web searches to browsing through papers. If no obvious source exists, searchers must use several non-specific information channels in order to fill their information needs.

3. STUDY DESIGN

3.1. Research problem

The research theme is to describe information searching and use of information resources in a city administration context. The subjects are performing their authentic tasks in their own workplace. Due to this naturalistic research framework, we are able to investigate information searching as a part of the ensemble of tasks and the real demands of searching. Our hypothesis is that there is a lot of integration of different information resources when performing a task, i.e., a single information resource alone is not enough to meet the information needs. We look at searching and the use of information resources from the task complexity point of view. Complexity refers to the perceived task complexity and the task performer's knowledge base concerning the task. The research problem is, in a nutshell, as follows: How does task complexity affect information searching and the use of information resources in the city administration domain? The sub questions include: 1) What information resources are used in tasks of different complexity? 2) How much and what kind of information searching is performed and are there any differences between different complexity stages? 3) What kind of problems do occur during task performance? and 4) Is there integrated use of multiple information resources?

3.2 Research setting and research subjects

Tampere is a city of over 200,000 inhabitants. Its service production is based on the purchaser-provider model. The city orders and invites to tender for the statutory public services. The private sector can act as the producer of these services but the city can also produce a part of them itself. The model is aimed at economic savings and improving the leverage of the inhabitants compared to the more traditional, strictly hierarchical city policy. The purchasing section of the administration answers for the background work of the ordering of the public services and the purchasing committees conclude the agreement with the service producers.

The participants in the study were six people working in the purchasing sector. Three of them were mainly in planning duties (two planning managers and a planning officer), three of them in administrative duties (two decision preparation secretaries and an administrative co-ordinator). The planning duties included, among other things: participation in strategic planning, laying guidelines and definitions of policy, developing the service network in teams, preparation of the decisions of people elected to a position of trust, inviting to tender and intra-organizational purchasing of public services. The administrative tasks included, among other things: compiling and putting out agendas and minutes for committees, councils and the city board, writing declarations, sending extracts of the minutes and calculation of honoraria and filing. Initially, we had seven participants but we were forced to stop data collection with one participant because of lack of suitable tasks for the study at hand. The recruiting of the subjects was made internally in the city administration without the association of the researcher. After getting their contact information, we contacted them by email. We also asked them to participate in a shared meeting in the Tampere administration office building. All but one of the then seven subjects were able to participate. During the meeting, they were informed about the purpose of the study and the data collection methods. After the meeting, they were asked to fill the orientation form containing questions about their background information. We were able to begin the shadowing sessions after the background data were collected.

3.3. Data collection methods

Forms

Three different electronic forms were used in data collection; an orientation form, a task initiation form, and a task ending form. The subjects filled in the orientation form only once before all other data collection. It was used to collect background information such as full contact information and information about their education and occupation. We also asked about their tasks, information systems and information sources in order to get orientated towards shadowing.

The task initiation form was filled in before every task in order to collect information about the research subject's presumptions and expectations regarding the task. We asked the subjects, for example, to describe the task at hand and their role in performing it. In this form, the task complexity was studied from two perspectives. One was the perceived task complexity and it consists of two questions: "*How complex do you think the task will be?"* and *"How sufficient is your expertise for the task"?* The other perspective was the task performer's priori knowledge of 1) the task process, 2) the task outcome and 3) the information needed to accomplish the task. The better the task is known *a priori,* the simpler the task. All questions concerning complexity required a percentage as an answer. In the end of the form we also asked about the information resources the task performer is planning to use and what information she expects to gain using them.

For every task initiation form a task ending form was filled after the task in question had been completed. Firstly, we asked some background information (the task performer's name and task description) in order to be able to combine the information in the beginning and the end forms correctly. We also asked how satisfied the subjects were with the outcome of the task. The subjects were asked to fill in all the sources they used, what kind of information they were looking for and if found, how satisfactory the information was. The most important question was how complex they felt the task was. The answer was given, again, as a percentage. It was used as one component when defining the task's perceived complexity. We emphasize the importance of studying complexity after the task completion, too, because the first estimate is not necessarily the one that will represent in the actual task performance.

Shadowing

Shadowing is a qualitative data collection method that can provide real time information about the research subjects' actions. Shadowing is one type of observation. The difference is the role of the researcher: she is not totally passive outside monitor of the situation but asks additional questions to the shadowee whenever needed. The shadower does not, however, participate in doing the tasks themselves. Because shadowing is a kind of interactive observation, it may work out some of the problems found in more traditional observation methods. These include the researcher's difficulties in understanding the reasons of the actions taken and the problems when observing desktop working, for example. Nevertheless, the shadowing encompasses the same data reliability issues as observation. E.g., the effects of the so-called theatre factor are impossible to detect: the subjects may act atypically because of the presence of the shadower and they may not recognize it themselves. However, it is found that the subjects get used to the shadower in the long run. Typically, the shadowing periods are long, lasting e.g. months, so it is likely that both the shadower and the shadowee become accustomed to the other. Shadowing is strenuous for both sides: the researcher must be alert all the time and the subject has to be prepared to tell her about the tasks when prompted. [11] [24]

The shadowing sessions took place in February-May 2011 in the shadowees' workplace during normal working days. We mostly contacted the research subjects via email in order to agree on suitable days for shadowing. Sometimes the next shadowing session was arranged right away after the previous one. The shadowing started on the agreed date in the shadowee's office where a camera was put around her neck and the shadower sat next to her. Initially, we talked about the tasks at hand and the course of the day. The participants were asked to fill in the task initiation form before the shadowing if possible. Otherwise, the form was filled in at the beginning of the session. Over the time, the subjects got used to independently filling in the forms when they started a new task as well as at the end.

Shadowing was really intensive: normally, we had to make notes all the time as we did not want to miss any potentially important information about the task performance. The shadowing situation was made as usual a working situation as possible. The subjects were encouraged to do their tasks the way they would without the shadower. A normal day would include interruptions, meeting other people and pauses. The researcher followed the shadowee even to the recreation room but without the shadower's role.

We tried to be neutral when monitoring the task performance. This included avoiding advising. However, we asked the shadowee questions whenever needed. Typical questions were why some action was taken in a particular way or where some information or message came from. Mostly the subjects told us about their actions at their own initiative. Alongside the notes we recorded the passages where the shadowee started to tell us about their tasks in general or describe the actions on a computer screen. For voice recording and making notes we used a smart memo pen that enabled importing the notes directly to the computer. The recording is linked to the spot that was written while recording. During the shadowing sessions, the shadowees wore a light tracking camera around their necks. The camera took a few photographs per minute depending on the illumination and the person's movement. When analyzing the data, the pictures helped us to recall the events during the shadowing sessions. A similar camera and shadowing technique was used while studying information interaction in molecular medicine. [18]

The sessions lasted from one to five hours (about two hours on average) and they included both working at one's desk and visiting colleagues' offices. Normally, the shadowing session ended at shadowee's request or when all the tasks agreed in advance were finished. There were no situations where the shadowee would have chased away the shadower. Naturally, it would have been the subject's right if the shadowing had become too disruptive.

3.4. Analysis

In the analysis phase, we aimed to describe the tasks, their complexity, information searching and information resources as well as their interrelationships. We already got an intuitive picture while collecting the data. This picture was specified through analysis methods. The data were reduced to a less narrative form through qualitative and quantitative analysis.

The final data was collected in 38 shadowing sessions. It consists of approximately 250 pages of handwritten notes, less than 20,000 photographs and 59 pairs of task initiation forms and task ending forms, in other words, 59 tasks. Only the tasks with both forms and shadowing notes were analyzed further. We had to interrupt data collection with one subject due to the lack of suitable tasks, so the final data consists of tasks performed by six subjects.

The most important part of the shadowing data is the field notes. We did neither systematically analyze the photographs nor transcribe the recordings as they were only meant to support the correct interpretation of task performance. It was easy to recall the sessions from the photographs as well as some – otherwise unclear – transitions between information resources. On the recordings, the subjects expounded the backgrounds of the tasks. The time stamps on the recordings helped to delete the interruptions (e.g. phone calls and visitors) from the data.

The analysis stage started with coding of the data. We marked all entries containing a time, an event, an action, a problem, a search, an information resource etc. This information was joined with information concerning the task complexity. In the study at hand, we had two approaches to task complexity. One is the perceived task complexity; the other one is the task performer's *a priori* knowledge of the task. The perceived task complexity is based on the information in the task initiation and the task ending forms. We decided to calculate it as *(100 - expertise + compl.begin + compl.end)/3*, where expertise is the inverse of complexity. "Compl.begin" is the subjective estimation of the task complexity before the task completion, and "compl.end" the same after the task has been finished. This formula is a straightforward and practical average of the three components of perceived complexity. The other indicator of task complexity, *a priori* task knowledge, is based on those questions in the task beginning form that deal with task performer's *a priori* assessment of the percentage level of beforehand knowledge of the task process, the information needed, and, the outcome of the task. It is calculated as *100-(process + information + outcome)/3*, where all *a priori* knowledge is the inverse of complexity.

We identified five main categories of information resources, each with sub categories. Every information resource belongs to one category only without exceptions. The categories are as follows: 1) *Systems provided by the organization* (SPO) are used to searching, sharing, producing or handling information. They are available through a single interface. All other networked sources belong to a category called 2) *Network*. Network has the sub categories *Internet*, the organization's internal *Intranet* and *Shared files*. Shared files are used on network drives.

The category 3) *PC* contains all those information resources that reside locally on the employee's own computer. This includes the sub categories *Programs* (e.g. word processors) and *Files*.

Category 4) *Communication* is self-explanatory. Communication can take place face-to-face (the sub category *Person*), in the *Telephone*, via an *Instant messaging program* or via *Email*. All other information resources belong to the category 5) *Manual.* The sub categories are *Papers, Publication*s (e.g. books and paper calendars), handwritten *Notes*, *Printouts* and *Other*. Notes and Printouts include only those resources that were created during shadowing. We wanted to identify situations where the subjects preferred using printouts to computer screens when reading or making notes. Any mail or internal mail (hardcopies) belong to the category *Paper*. Category *Other* represents the remaining manual resources.

All information resources are not equally important. Therefore, we classified the information resource uses in task performance into importance classes: each resource got the value 1 (if it was used at all), 2 (if it was an important resource in the process), or 3 (if it was the most important resource). These weighted values were used sparingly in order to get as clear differences between the information resources as possible. For every task, the single most important, and a few important information resources were selected. The weighted values are justified by the shadowing sessions and the data. We analyzed the new weighted use values and the non-weighted values in parallel and compared them. The intra-rater reliability of the resource use weighting was assessed by reclassifying all resource uses in ten tasks three months after the initial classification. The weighted values were exactly the same in 68% of the cases, and exactly or almost the same in 97% (the difference being +/- one point compared to the original weights).

The quantitative data analysis included representing tasks in each complexity category through numeric features, such as the absolute number of searches and their relative division across various information resources, the relative importance of information resources in terms of use and weighted use, and the changes in these numeric features between complexity categories.

We used Pearson's correlation coefficient to explore the variables' correlation with each other. As this is not an explanatory study, we did not perform any statistical significance tests. This decision is also supported by the relatively small data set and data collection methods that mostly back qualitative inspection rather than sampling aiming at representativeness.

4. Findings

4.1. Central variables

Task complexity

We have two perspectives to the complexity of the tasks included in the study. They are (a) the perceived task complexity and, (b) the task performer's *a priori* knowledge concerning the task process, the information needed and the outcome. According to the Pearson correlation coefficient, the correlation between these two perspectives is 0.71, which means that approximately a half of the variation in one variable can be explained by the variation in the other variable. Consequently, it is probable that the sparser the task performer's *a priori* knowledge, the more complex the task is perceived. The level of complexity indicated by these two variables varies - the strength of the *a priori* knowledge indicating less complexity than the directly perceived complexity – but this is an artifact of the measurement of the variables. The perceived complexity seems to affect the task performance (e.g. selection of information resources) more than the level of *a priori* knowledge. We cannot make any direct comparisons to other studies concerning task complexity because of differently set and defined complexity categories. However, our findings can be used as a base for a more general contrasting as we used same kinds of complexity indicators as, e.g. Kumpulainen and Järvelin [19] (*a priori* knowledge) and Byström [5] (*a priori* knowledge and perceived task complexity).

On the basis of the perceived complexity, the tasks in our data can be divided in three complexity categories as follows: 16 simple (complexity less than 20%), 20 semi-complex (20-39.9%) and 23 complex tasks (40% or more). Complexity varied here from 5% to 70%. In order to approximately match these classes based on the prior knowledge complexity, we classified the tasks as follows: 18 simple (complexity less than 10%), 21 semi-complex (10-19.9%) and 20 complex tasks (20% or more). Complexity varied here from 0% to 53.3%. The categories are shown in Table 1 and the relationships of the two complexity measures in Figure 1.

Table 1. The number of tasks across complexity classes

Measure	Simple	Semi-complex	Complex	N
A priori	18	21	20	59
Perceived	16	20	23	59

Both complexity categorizations are based on the task performer's own estimates. The results might have been different if we could have measured the amount of their *a priori* knowledge objectively. We decided to trust these estimates because there is no unobtrusive and simple way for such measurement. People in mostly planning duties tended to regard their tasks more complex (average task complexity 41%) than the administrative staff (average 25%). Planning personnel also had less *a priori* knowledge about their tasks. Leckie, Pettigrew and Sylvain [21], among others, state in their model of the information seeking of professionals that work roles affect tasks and tasks have an effect on the nature of information needs. We did not study these aspects further as work roles were out of the scope of our study; we concentrated on tasks rather than performers. Additionally, we had only six subjects representing roughly two different work roles.

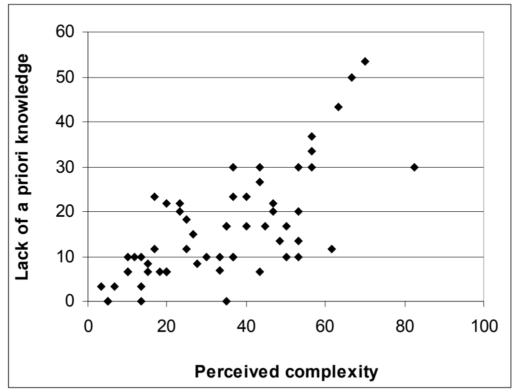


Figure 1. The correlation between the complexity measures (N=59). There are only 53 data points visible in the figure, as some of the points overlap.

Information resources and their integrated use

In task performance, 2-12 different information resources were used, on the average 6.5 per task. The most used information resource class is *Manual* (25.8% of all information resource use). Manual information resources include five subclasses, which were fairly easy to identify in the data. The most popular subclass of Manual is *Paper,* which was used in 36 tasks. Paper is needed when filing records, delivering notes, receipts and contracts missing from the systems. The manuals of systems may be preferred on paper and some people experienced it easier to follow the agenda in meetings on paper than on laptop computer's screen. The entries on the paper agenda could further be exploited when taking the minutes to the system. One of the subclasses is *Other* that contains the few occurrences of those resources that did not fit naturally in any other class. These include scanner and pocket calculator. The popularity of the class Manual suggests that people convey a lot of information still in paper form, for instance. When Manual resources are used in a task, there tend to be several of them in the same task: 12 tasks in our data did not contain any manual information resources, ergo the substantial use is spread over just 47 tasks.

Communication resources were utilized in most tasks. Only five of the 59 studied tasks did not involve any use of Communication resources during the shadowing situation. Communication was mostly handled via email. The email program used in the target organization included several functions. In addition to sending and receiving messages, the shadowees shared documents via email both as attached files and through links to files on shared servers. The email program enabled them to examine their own and colleagues' calendars and add notes to them. According to their weighted use, Manual information resources and Communication resources were clearly the most important resources.

During the shadowing period, we observed the shadowees to operate 15 different SPOs. The SPOs were used for searching, conveying, forming and saving information. Most SPOs provided many different functions and the same systems were used by several user groups: e.g. travel-expenses accounts were updated, checked and accepted in the same system.

There exist at least the following types of *integrated use* of information resources: The resources can be used separately in different phases of the task process or they can be used almost simultaneously when information from two or more sources is compared or when information is being transferred between systems. People may also change over from one information resource to another due to a failure or imperfect information. In case of electronic information resources, the integrated use is forced or directed by integrated functions, too. It is not easy, however, to tell apart these seemingly obvious cases from the empirical data. Naturally, all information resources used in a task performance are somehow in interaction as they share the common task goal. It is problematic to define even simultaneous use of resources because a task performer can only turn her attention to one resource at a time even if the alternation may be rapid. In our study, we interpreted as integrated use all use of information resources within the same task performance.

Query-based searching

During the shadower's presence, in all 202 recognized searches for information were performed. Altogether 24 tasks did not contain any information searching and at most 27 searches were run during one task performance. The Manual information resources are the only category that does not enable information searching by its nature. We reckoned both free-form textual and faceted (e.g. through drop-down menus) searches among the searches. The latter were sometimes hard to identify in the data as the target organization did not allow any logging. Especially problematic were the situations were similar searches were done in the same system successively within a short period of time. In the analysis stage, only the definite searches were counted and analyzed. Writing a known URL address to the browser's address bar was not regarded as an information search.

The majority of information searches was directed to the SPOs (67%) and the rest to networked resources (Internet 24% and Intranet 7%). Two free-form searches were made to the email files, too.

Almost all searches had an important role in the task performance. Typical searches were of fact-type, i.e., addresses or statistics. Sometimes also known-item searches occurred. Subject searches were rare; narrower information needs were more common. An example of a subject search in a planning task situation is as follows: The task performer wants to see a picture of an area. She supposes there is one but does not know where or in which format. She starts searching by navigating to the organization's external website in the town plan section. As she gets no results, she switches to an Internet search engine and searches by the name of the area. No satisfying results are found, whereupon the originally well-specified information need changes to the form "*any information about the area"*. She returns to the organization's website and searches by the name of the area. After revising the spelling she finally finds a reference to a record where the subject is being discussed. She explores the rest of the results and goes to the subsystem, which contains all records and agendas. There she finds the useful record by searching with a date. In this example, the information search was not originally a topical search but turned into one because there was nothing to satisfy the more exact information need. In real-life information searching situations, the searcher may modify her courses of action, even the information need, according to what is found in the systems. So, the information need and the information searching process are dynamic [3].

There are three main reasons why a task did not involve query-based information searching. Firstly, some - mainly routine - tasks involved using known documents to produce a new document (e.g, in a case of forming an agenda) or to convey them forward. Task performers already had the documents (and information) needed in front of them or in a system where they could be found after short browsing. Secondly, some tasks were quite the opposite: They were a part of so broad planning projects (or equivalent) that meetings were the relevant way to get information concerning, e.g. sentiments of colleagues and residents. Finally, we were able to study information searching taking place only during the shadowing. A few tasks most likely would have included query-based information searching after the shadowing session but we could not capture it.

4.2. Complexity categories

In this section, we discuss the results according to task complexity. In each complexity category, we discuss the information resources used, information searching and problems encountered.

Simple tasks

Information resources. Approximately six different types of information resources are utilized in simple tasks, mostly of the Manual and PC type. The SPO resources are used a bit less but they are almost as important as the most used information resources. Communication resources have a fifth of all information resource use. Network resources are not important and they are used very little, under 10% of all information resource use.

In simple tasks, a lot of information is still kept in paper form. Typically, information is transferred from paper to an SPO. These information systems seem to serve the task process well in simple tasks where the task process can be described in advance and thus can be potentially automated at least partly. If, in addition to SPO and Manual resources, extra information or files are needed to perform a simple task, they can mostly be found on the task performer's PC. Therefore Network resources are rarely used. Sporadic files were found in Shared files or in the Intranet. The Internet is used for example when some extra-organizational contact information is needed.

Information searching. In a simple task, approximately three searches are performed. Evidently, the most of them fall on SPO. It is typical to search for documents (e.g. travel-expenses accounts) by a person's name in order to process them. Thus, the information need is of fact or known-item type. Often, the searches take central stage in the performance of a simple task because they are vital for navigating in an SPO. The rest of searching (10-20%) happens in Network resources.

Problems. There are somewhat over four problems during a simple task performance. The majority of them concern SPOs (slowness), information contents (a false name) or personal computers (distracting automated features in word processors). Surprisingly, most of the task performers' own mistakes are made in tasks that they are well familiar with. For example, an SPO is activated but they forget to look up the information needed or wrong data is copy-pasted from a file to another. Possibly simple tasks are so well-trodden that they can be quickly performed and no high concentration is needed and so the number of careless mistakes increases.

Semi-complex tasks

Information resources. Approximately seven different types of information resources are used in a semi-complex task performance. The most common are Manual information resources though they are used less than in simple tasks. Paper is the most common sub category of Manual in this complexity category. The use and importance of SPOs get smaller compared to simple tasks. These systems are still a more important part of the task performance than could be expected based on their frequency of use. The use of Network resources seems to increase at the expense of SPOs: an SPO offers information in a specified form to those tasks that can be exactly described beforehand. The task performers expect that Network resources contain more heterogeneous information whereupon they consult Network when the information need is unclear or they do not know where to start searching for the information.

The importance and use of Communication increase a little compared to simple tasks. Communication is especially central in the tasks that are semi-complex based on *a priori* knowledge. In this complexity category, Communication is more tightly related to the complexity measure (perceived/*a priori* knowledge) than to the importance measure (amount of use vs. weighted use). Other people are used as information resources even more often than the generally most used Manual resources in semi-complex tasks. Thus, when the amount of *a priori* knowledge decreases when proceeding from simple tasks to semi-complex, people tend to use as flexible information resources as possible (that is other people) despite the perceived complexity.

Information searching. The number of information searches varies from three to five per task based on the complexity measure in this category. The most of the searches are performed in SPOs (68%).

Problems. There are over five problems in each semi-complex task. The majority of problems are confronted when using SPOs. Personal computer and information searches are still substantially problematic.

Complex tasks

Information resources. On average seven different types of information resources are used in complex tasks. As SPOs are often most suitable for conducting clear processes, their use in complex tasks is least important among information resources, only 9% of information resource use cases in complex tasks (based on *a priori* knowledge). SPOs are still more important than used. The use of different SPOs is more evenly distributed than in simpler tasks. Also a few new, before unseen SPOs, are used in complex tasks.

Other information resources are used quite evenly. The Programs and Files on PC are not enough anymore. They are still used but they are only a little more important than SPOs. The use of PC is more frequent than it is important. In tasks perceived as complex, Manual resources are used substantially less than in simpler tasks. The use of Network resources is still growing compared to simpler tasks. Mixed information, files and functions are found in Intranet, Internet and Shared files. These information items are not available in SPOs and they have not been saved to PC perhaps because they are rarely needed.

Communication, which is quite a flexible information resource becomes the most used and most important resource in complex tasks. It gets 28% of the weighted use points in tasks that are perceived as complex. It seems that when people perceive complexity, they tend to consult other people or exchange information bypassing the more official channels, e.g. SPOs. Collaboration in form of meetings increases, as large planning tasks require this. Email is clearly the most important and most used among Communication resources.

Information searching. While shadowing, we observed approximately two to four information searches depending on the measurement of complexity. The low number may be due to few searching oriented complex tasks. A possible explanation may be that the tasks about which their performers have poor *a priori* knowledge, cannot be served through information searching as it is hard to describe what one does not know. In addition, the complex tasks in our sample concentrate on quite broad planning tasks. In them, all the information needs are not describable as information searches or the needed information does not exist in searchable form (for example the opinions of the people in charge of zoning or the identity of the most suitable applicant). The distribution of information searches is even between SPOs and Network resources: slightly over a half in SPOs, slightly under a half in Network resources.

Problems. There are approximately four problems in complex tasks. It seems that problematic tasks are perceived complex and the problematic nature does not necessarily affect the amount of *a priori* knowledge. As in simpler tasks, too, the problems are mostly caused by SPOs even if the use of SPOs is very low. The contents of information and missing information resources are still as problematic as in simpler tasks. Examples of problems include malfunctioning or slowness of SPOs or serious deficiency or incorrectness in information contents; e.g. a wrong date in a record preventing finding of additional information.

Summary

The results suggest that task complexity has an effect on information searching and use of information resources. In Table 2, we summarize task features in each complexity category through numbers for both interpretations of complexity; in Table 3, typical task features are described verbally. Figure 2 and 3 show the distributions of the importance and the use of different information resources in each complexity class.

Table 2. The number of information resources, searches, and problems across complexity classes based on *a priori* vs. perceived complexity

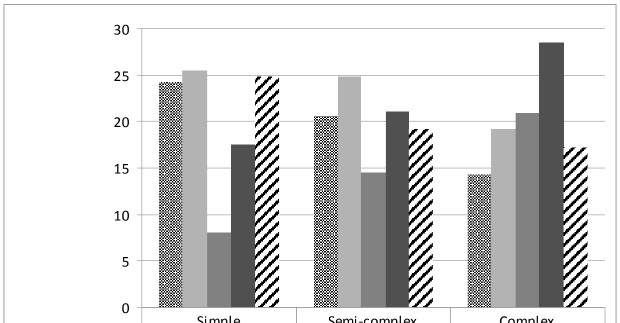
Task Complexity	**Information resources**	**Searches**	**Problems**
	based on *a priori* vs. perceived complexity		
Simple	*6,2* / 6,1	*3,0* / 2,8	*4,5* / 4,1
Semi-complex	*6,8* / 6,8	*4,8* / 3,4	*5,2* / 5,5
Complex	*6,5* / 6,6	*2,4* / 3,9	*4,2* / 4,3

One may notice in Table 2 that the number of information resources used per task does not vary much across task complexity classes based on either interpretation of complexity. The same holds for problems encountered. Perceived task complexity appears to lead to more searching as task complexity increases but there is no clear trend when complexity is measured through *a priori* knowledge.

Table 3. Examples of information resources, searches, and problems across complexity classes

Task Complexity	Information Resources	Searches	Problems
Simple	Resources on PC, extensive use of e-mail	Factual searches to organizational information systems	Minor usage problems with information systems or PC
Semi-complex	Various ways of communication, network resources focal	Factual searching and searching for important files in information systems and network resources	Problems with information content: missing information, shortcomings and missing files
Complex	Communication and web resources focal	Searching for several information types. Searches important or side tracks in tasks	Many tech. problems due to awkward resources or lack of skills. Problems with missing information

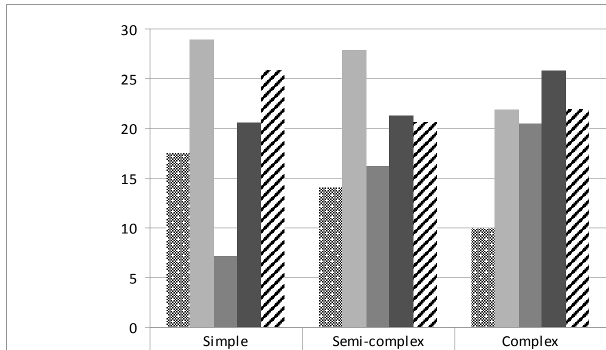
Simple tasks are typically routine and are performed in systems built for them. The task can be performed quickly and it may contain several short repetitive rounds. The problems encountered are not serious and they can even be predictable. In semi-complex tasks, the task procedure and the information resources needed are mostly known beforehand but the tasks require context-sensitive discretion and problem-solving skills. Typically, semi-complex tasks are not routine in that they are not performed often enough. Complex tasks are new or somehow unpredictable for the task performers. The performer may not know exactly the location or contents of the information or documents needed. There are several wild cards in a complex task and it is partly because of them that the task is performed step by step - repeating cycles cannot be formed. In addition, task performance is tinged by trial and error.



	Simple	Semi-complex	Complex
Systems	24,2	20,6	14,2
Manual	25,5	24,8	19,2
Network	8,1	14,5	20,9
Communication	17,5	21	28,5
PC	24,8	19,2	17,2

Figure 2. Distribution of importance of information resources across complexity levels based on perceived task complexity (%)

We summarize the distributions of the importance (Figure 2) and the use (Figure 3) of different information resources in each complexity class only based on perceived task complexity. The other complexity interpretation yields essentially the same picture; the differences between the minimum and maximum are slightly greater by perceived task complexity. Figure 2 shows that, as task complexity increases, SPOs (systems), Manual resources and the PC lose importance, whereas Network and Communication resources gain. By the frequency of use (Figure 3) the overall trends are the same but SPOs (systems) and Manual resources lose status steeper as tasks gain in complexity. The PC retains its position better. The frequency of use of Communication resources does not vary as much as their importance across complexity classes.



	Simple	Semi-complex	Complex
Systems	17,5	14	9,9
Manual	28,9	27,9	21,9
Network	7,2	16,2	20,5
Communication	20,6	21,3	25,8
PC	25,8	20,6	21,9

Figure 3. Distribution of use of information resources across complexity levels based on perceived task complexity (%)

5. Discussion

By using the shadowing data supplemented with the forms, we were able to draw a picture of real information behavior in the public administration domain. Various kinds of information resources were used during task performance and the level of complexity seemed to affect the usage of resources. While the average number of sources used remained stable across task complexity classes, the frequency of use, and importance, of each type of resource varied according to task complexity. SPOs, manual resources and PC were frequent and important in simple tasks, but lost their standing in complex ones to Network and Communication resources. This is natural: SPOs are more easy to define for simple tasks, they further simplify the tasks they are designed for, and it is difficult and/or non-productive to develop systems to support rare, unexpected or difficult tasks.

Query-based information searching took place in 35 tasks. Most of the information searches were directed to the organization's information systems, and the rest to Network resources. Tasks that were shadowed were quite typical administrative tasks, and we could argue that their own systems helped them quite well with their daily task performance. When the task complexity increased, the Network resources became more important, and so did the use of people as an information source (cf. [5]). This might be due to a need for contextual and procedural information, which could not be found in the documents in organization's information repositories. The participants were dynamically adjusting their search behavior during the work task process and their needs were evolving while searching. This is similar behavior to Bates' berry-picking (see [3]).

Most of the problems occurred with SPOs, and they took place in semi-complex tasks. The administrative staff also had problems with the systems on their own computers and doing successful information searches was substantially problematic. The most typical problem was that the information searched for was not found. Quite often this was not the searcher's fault (e.g., poor search terms or ill-defined information need) but the systems failed to match relevant information.

The resources were used in an integrated way, but the level of automation of course varied based on the type of the information resource. There was manual integration (e.g. resources used in sequence during task performance or simultaneous comparison) and semi-automatic integration, e.g., when information was transferred between systems upon task performer's action. Switching between systems occurred due to a failure or missing information (one source not covering all the information needed). Automatic integration was obviously available only in case of electronic sources. Here the city's long-term aim to design and rationalize administrative processes resulted in systems for simpler tasks, which probably integrate task-relevant pieces of information.

The present findings cannot be directly compared to Byström's [5] earlier ones due to issues in data set comparability. However, the present findings tell about task-based information searching in modern digital city administration, where information systems have been engineered to support administrative task processes. This development was just beginning when Byström collected her data. Still, simple searching in internal resources dominates simple tasks whereas people and searching in external resources dominate complex tasks. Byström's [5] use of "official documents" and "registers" are replaced by the use of SPOs.

The findings can neither be directly compared to Kumpulainen and colleagues' [19] earlier ones due to different task domain (research in molecular medicine) and somewhat different measurement of task complexity. Nevertheless, the tasks analyzed in the present study seem simpler on the average and the information system environment more integrated than in [19].

Methodology. Using forms and shadowing technique, aided with tracking camera and a smart memo pen, is a suitable way of collecting data for the study of task-based information searching. However, the data could evidently be improved by additionally collecting log data, or by video recordings, but this was out of question for organizational data protection policies.

Consolidation of the proposed methodology allows interesting longitudinal studies that analyze the consequences of developments in information (access) systems in task processes. This also allows the identification of systems that are frequently used together, which suggests the mutual adaptation of such systems [19].

Limitations. The present study was conducted in a specific organization in a specific domain, during a given time and place. Possibilities to replicate this kind of research is, no doubt, limited because the tasks change over time and the situations are dynamic. However, systems used for similar tasks are similar and the same variety of systems might be used together for reaching the task goal. This kind of integrated use of multiple systems is often ignored in system design though it should be supported.

6. Conclusions

In this study, we focused on task-based information searching and use of information resources by shadowing tasks of people working in a city administration. Shadowing field notes were triangulated with photographs and voice recordings. In addition, we used questionnaires, which the task performers filled in before and after every task. We regarded task complexity as the key factor affecting task performance. Complexity was defined from two different perspectives that both were based on the task performer's written estimate. The perspectives were the task performer's perception of complexity and the amount of her *a priori* knowledge concerning the task. We found that the studied 59 tasks concentrate toward the simple end of the two metrics, especially according to the amount of *a priori* knowledge. The variation of perceived complexity was wider. In both cases, however, we were able to classify the tasks into three classes with good correlation. It is challenging to define *objective complexity* precisely; complexity is perceived subjectively. The perceived complexity correlates quite strongly with the lack of *a priori* knowledge.

Our results suggest that task complexity affects information searching and use of information resources. Information resources on the task performer's computer, manually accessible or information systems provided by the organization (SPOs) dominate simpler tasks whereas Network and Communication resources dominate the complex ones both in terms of the frequency of use and importance. Further, the more complex the task is perceived, the more searches are done. The searches, too, change over from SPOs to Network resources, i.e., Internet and Intranet, as complexity increases. The differences in information searching between complexity categories were often the most obvious between simple and complex tasks. The special features of semi-complex tasks were harder to interpret.

We cannot generalize our results because the study took place in a specific domain at a specific time, and the subjects were not sampled within the organization studied. We can nevertheless say that the results add to the knowledge on task-based information searching in the context of real life information access, city administration in particular. Though we had only six subjects and relatively small number of tasks, the data were rich and included 384 information uses and 202 searches during a three-month period. A search logger would have increased the accuracy of the observational data, but the use of such a tool was not allowed in target organization studied. Nevertheless, as the study took place in a natural, real-life environment, we were able to get a realistic picture of the real tasks and information searching in context.

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Task complexity affects information use: a questionnaire study in city administration

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Abstract

Introduction. The purpose of this paper is to study information types in the context of simple, semi-complex and complex tasks in city administration. Task complexity has proved an important aspect of information seeking practices.
Method. Employees of a city administration completed questionnaires when initiating and finishing their work tasks. Questions concerned task complexity, information use, task performer's role and *a priori* determinability of the task, for instance.
Analysis. The data comprised of fifty-nine tasks performed by six participants. The tasks were divided in categories based on their perceived complexity. Thereafter, information types expected at the beginning of the tasks and materialised at the end were statistically analysed within and between complexity categories.
Results. The study found that task complexity affects information use significantly. Our results partly corroborate earlier findings by Byström in partly the same organizational setting. Her findings concerned only materialised use, whereas we analysed expected use and differences between these two, as well.
Conclusions. The more complex the task, the less facts and the more information aggregates are used. The use of known-items was independent of task complexity. Overall, external information is used little but more in complex than in simple tasks.

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Introduction

People perform various tasks both during their working and leisure time. Some of these tasks include information seeking and searching. In order to be able to explain variation in information seeking practices, it is important to understand the underlying task and its characteristics. The knowledge on the features of task performance contributes to the development of more suitable information systems and information seeking or working practices. Especially task complexity has proved to have a notable effect on information seeking practices: the more complex the task, the more complex information needs and information seeking. People also tend to underestimate the information seeking needed in complex tasks and overestimate it in simple tasks. (Byström 1999).

Task-based information seeking has been investigated using a range of approaches and methodologies. Vakkari (2003) has written a thorough review of task-based information seeking research and Ingwersen and Järvelin (2005) emphasise the need for a research programme that would combine the findings of information seeking and information retrieval into a task-based paradigm. The concept of task and task characteristics have been theoretically elaborated by, for example, Li and Belkin (2008), Byström and Hansen (2005) and Campbell (1988). Task-based information seeking and searching research has covered various domains, such as city administration (Byström 1999; Saastamoinen *et al*. 2012), patent domain (Hansen 2011), academic research (Wang *et al*.2007) and molecular medicine (Kumpulainen and Järvelin 2010), not to mention the research on students' task-based information activities (Kuhlthau 1993; Vakkari 2000; Vakkari *et al*. 2003).

While there are several studies on task-based information seeking, the domain still needs more research on different tasks in different domains. The present study focuses on tasks in administrative context. The studied tasks are real work tasks that are performed by real performers in real situations. The tasks are classified according to their complexity. Our study contributes to the knowledge on task-based information seeking in the administrative domain. It is a successor of Byström and Järvelin's (1995) and Byström's study (1999) because it was partly conducted in the same city administration context (Byström (1999) had two cities in inspection) and thus in the same working environment with a similar approach. However, they did not analyse the expected information needs. In our study, we compare expected and materialised information use. Naturally, administrative working settings have changed quite much especially regarding their information environment. In the 1990s, it was common that there were only a few independent. computerised information systems in use in an organization, and the Web was just emerging. Comparing the results of these two studies contributes to understanding the evolution of information seeking activities in organizational settings.

The specific research questions in the present paper are:

1. What are the shares of internal and external information and how do they deviate across task complexity categories?
2. What are the expected and materialised information types and how do their shares deviate across task complexity categories?

This study is a part of a larger research project, where the participants were shadowed, in addition to the questionnaires. The results based on the shadowing data are discussed in Saastamoinen *et al*. (2012).

The paper is structured as follows: first, we make a brief review of related studies. Secondly, we present the methods and data of the study. Then we discuss the findings, and finally, the research questions are answered in the conclusion.

Literature review

Byström and Hansen (2005), Li and Belkin (2008) and Vakkari (2003) discuss the concept of task and the different aspects task performance has in information studies literature. For example, in the information seeking model of Leckie *et al*. (1996), work roles affect tasks and tasks affect the nature of information needs. Moreover, Byström (1999) finds that the level of ambition is connected to task types.

Task complexity is one of the key features of tasks. The use of task complexity in informing sciences has been reviewed by Gill and Hicks (2006; see also Cohen 2009). Task complexity has been defined in many ways in research. According to Campbell (1988), these interpretations of task complexity can be divided into three major categories: task complexity is either a) mostly caused by the features of task performer; b) caused by objective features of the task; or c) a combination of these two.

Byström and Järvelin (1995) divide tasks into five complexity categories according to the degree of *a priori* determinability of task information, process and outcome. The extremes are automatic information processing tasks that could be fully automated and genuine decision tasks that are caused by completely unforeseeable upheavals. This classification is modified into three categories in Kumpulainen and Järvelin (2010), where each task session is assigned a complexity category depending on how many of the three task components (resources, process, outcome) are known to the task performer beforehand.

A priori determinability of a task is highly dependent on task performer if estimated by the performer for a task at hand. On the other hand, we can argue that if estimated for more abstract task types, this complexity definition becomes more objective. That is to say that some tasks are more complex, demanding or unclear than others regardless of the performer, as argued by Campbell (1988). The objectivity of task complexity should not be a question of right or wrong, however. In fact, Allen (1996) found that the participants' actual knowledge affected information seeking less than the knowledge they perceived to possess. Similarly, Saastamoinen *et al*. (2012) discovered that participants' perceived task complexity has clearer effects on information searching than their advance knowledge of the task.

Li and Belkin (2008) base their theoretical task categorisation on earlier categorisations in information research literature. It is extensive but so multifaceted that it is difficult to exploit in empirical studies, though it may be applied when comparing the categorisations of different studies. In the categorisation, task complexity is divided in objective and subjective parts. Objectivity here means the number of paths between which the task performer has to choose during the task. They also have a different category called *difficulty*, which is said to be subjective. On the other hand, the researchers do not view *a priori* determinability either as part of difficulty or of complexity. (Li and Belkin 2008.)

The information seeking process is kindled by information needs. They can be described as anomalous states of knowledge (Belkin 1980) or as a gap to be crossed (Dervin 1983), for example. Further, Allen (1996) argues that information needs can only be observed indirectly, through information seeking activities. Case (2007) discusses different researchers' reasoning about information needs.

Eventually, an information seeking process ends up in information use. Kari (2010) discovers seven conceptions of information needs in information studies literature. According to Kari (2010), the conceptions vary from modifications in knowledge structures to consuming information instrumentally, or even producing new information. As a matter of fact, contemporary digital information environments enable almost simultaneous information seeking and information use as an information object can be gained, interpreted, modified, utilised and forwarded in a single session using a single computer, for instance (Blandford and Attfield 2010).

In the present paper, both information needs and information use are understood fairly instrumentally as parts of achieving the goal, the task outcome. The participants list potential information used in a task before commencing it; this can be interpreted as information needs. On the other hand, the listed information needs may as well be only on a prospective level; some information may not be even needed or used in the end, for various reasons. The list of used information in the end of the task obviously indicates information use of a sort but we cannot tell the nature of it. Nonetheless, the use is firmly connected to the benefits the information is expected to bring about.

Bearing in mind that information seeking is aimed at finding *information*, we study different information types and their relations to tasks of different complexity. Information types can be categorised on different levels of abstraction. Below, we will describe a few interesting categorisations used in research literature.

Byström (1999) categorises information into three categories based on its nature or ways of use: task information, domain information and task-solving information. Task information refers to information dealing with exclusively the task at hand. The information is typically in the form of facts (names, dates). The second information type, domain information, refers to general information dealing with the task subject. Thirdly, task-solving information indicates the means and methods to perform the task, e.g., information about what task and domain information is needed and what stages the task includes. In other words, task-solving information is methodological or procedural information. Additionally, a division between an organization's internal and external information sources is made. (Byström 1999.) We apply a similar internality division to information types.

Gorman's (1995) information types are closely related to Byström's (1999) though they are slightly more specific and named differently. Gorman (1995) outlines five types of information that physicians need in their work. Information needed may concern only one patient, statistics about patients in general, generic medical knowledge that can be easily extrapolated, procedural information (how to correctly perform one's own tasks) or social information (how others perform their tasks). (Gorman 1995.)

Morrison (1993) has similar information types to Gorman's (1995), although her categorisation focuses on the social aspects of work at the expense of substance matters of the tasks. Morrison's (1993) five information types concern procedural information, role expectations, expected behaviour both when performing the tasks and outside them, and performance feedback, that is, evaluative information about the task performance.

A typical way of classifying information searches is dividing them in known-item, factual and general searches (Ingwersen 1986, Toms 2011). We applied a similar classification to the information types in our data (see next section). This classification concerns clearly the form of the information, not its contents or expected uses and for this reason it can be easily applied to different environments and different tasks. Byström's (1999) *task information* resembles searching for facts (narrowly exploitable information) and *domain information* searching for general information (widely exploitable information), respectively.

In contrast to the examples above, Vakkari (2000) has two categorisations for information types in his study, namely types of information sought and contributing information types. This division resembles division between information needs and information use. Sought information has only three categories that describe how general the information is. By contrast, seven contributing information types represent more precisely the participating student group by categories such as theories and methods. (Vakkari 2000.)

Study design: participants, methods and data

The organization studied was the administration of a city of more than 200,000 inhabitants. The city arranges the statutory services based on the purchaser-provider model. The recruitment of the participants was taken care of by a contact person. After obtaining a name list we contacted the volunteers by e-mail and arranged a collective meeting with them to hear about their work and get them acquainted with the study. After that we sent them an orientation form to complete and began to agree on dates for data collection sessions by e-mail.

Our participants were five females and a male working in the purchasing sector. Two of them had subordinates. One half of the participants worked mainly in administrative duties, the other half in planning duties. The administrative duties included secretarial tasks such as preparing records and agendas, completing license applications and sending record excerpts. Planning duties included writing enclosures for calls for bids, replying to requests for account from other offices and untangling the effects of new residential areas on public services. The participants had working experience in same or similar tasks ranging from 1 year and 5 months to 25 years. Initially, we had seven participants in the study but unfortunately one of them had an insufficient number of tasks suitable for our study. We had to abandon data collection with this participant after a few sessions.

The questionnaire consisted of three electronic forms completed by task performers. Every participant completed an orientation form once, before the actual data collection phase. The questions concerned their work, tasks and information seeking. The purpose of this form was to provide the researcher with a preconception for the data collection (see Appendix 1). The task initiation (see Appendix 2) and task finishing (see Appendix 3) forms were completed at the beginning and in the end of every task. The questionnaire forms were founded on Byström's (1999) diary forms for ensuring the comparability of the results, and also because Byström's (1999) questionnaire was well tried. Only smaller revisions were made to the forms in order to better suit the present study and its specific research interests.

In the questionnaire forms, there were in all six questions concerning task complexity. In two of them, the task performer was requested to directly estimate the task complexity before beginning the task and after its completion. Three of the questions were about the task performer's own estimates of their knowing the task process, outcome and the information needed in the task beforehand. The more they knew, the simpler the task. In the final question, the participants were requested to estimate their expertise concerning each task. All these estimates were given in percentages. In the analysis phase, each task was assigned a composite complexity measure based on the questionnaire answers. The final complexity of a task is simply the mean of the five above mentioned complexity estimates; that is expertise, initial and final task complexity, the task performer's knowledge of task process and information needed. *A priori* knowledge of task outcome was omitted from the complexity measure. This was done because participants appeared to base their answers on different grounds; some understood 'outcome' as a content matter (such as the actual place where a school be established), some as the form of the outcome (such as the fact that the school will be placed somewhere).

Cronbach's alpha (1951) for the final composite measure of complexity was 0.79 (confidence interval 0.69-0.87), which is satisfactory. The tasks were divided in three complexity categories (simple, semi-complex and complex). Another way of calculating complexity from the same original data is demonstrated in Saastamoinen *et al*. (2012).

Mostly, we used task complexity categories in the calculations, but in some cases the exact complexity of each task was needed, such as when calculating Pearson's correlation coefficients. Categories were formed based on the size of each category so that each of them contained approximately equally many tasks. Above all the categories illustrate the tasks' relative complexity compared to other tasks in the data, as the object of the study is to compare information seeking in tasks of different complexities. Other categorisations were considered, but categories of different sizes could have caused distortions in the results because of the low number of tasks. Furthermore, the data did not seem to cluster in any natural complexity categories.

In the analysis phase, we compared tasks of different complexity categories regarding the expected and materialised use of information types. *Expected* information is information that participants expected to use during the task process (task initiation form) and *materialised* information is information they reported using after task completion (task finishing form). In the task finishing form, we also asked them whether the information was found and if it was adequate (on a scale of one to five). In addition to the expected and materialised information types, we calculated the distribution of dropped initial (not finally used in the task) information types, and unexpected new ones (not known to be used before the task), in each task complexity category.

We categorise information in two different ways: firstly, every piece of information mentioned in the forms is either internal or external to the organization regarding the place where it was produced. The second categorisation is between information types. The participants defined information (objects) in three quite distinguishable ways, which were 1) known items, such as a certain book or file without any explanation of what kind of information is desired from it; 2) facts, such as a name of a new manager; or 3) information aggregates, a subject or a bunch of facts needed.

In our main inspection all above mentioned information types are equally weighty and each piece of information is calculated once so that ten facts equal ten and an information aggregate equals one, for instance. In results section, we discuss both the mean shares and the absolute number of information types in each task complexity category. Mean share is the average proportion of an information type in a task complexity category, and mean count is the average number of an information type in a task complexity category, respectively.

We may argue that these information types can be arranged in order of growing complexity. Therefore we scored every information type according to its complexity. We scored them as follows: facts = 1, known items = 2 and information aggregates = 3. Information types in a task could obtain scores ranging from 1 to the maximum of 6, if all information types were needed. By comparison, we also changed this ordinal scale into the interval one and weighted the information types as follows: facts = 1, known items = 5 and information aggregates = 10. The information type complexity of a task could thus range from 1 to 16. These weighting factors are of course arbitrary but they provide further insight into the relationships of information types and task complexity. For the sake of comparison, we also counted the number of different information types in each task, ranging from 1 to 3.

Briefly, we ended up having three weighting schemes, namely 1-1-1, 1-2-3 and 1-5-10. In the weighting process, every information type was calculated only once so that for example one fact weighted as much as ten in a task. This decision had two reasons: firstly, the number of each information type used could already be seen in the unweighted measurements. Secondly, the complexity (i.e. diversity) of information types used does not increase whether there are for example several known items or just one. The complexity of information types is calculated both before and after task performance.

The distribution of the data and the number of, and the measuring level of, variables (nominal, ordinal *etc*.) set the preconditions in selecting suitable tests. The statistical tests applied and their significance levels are reported with the results.

Findings

Overview of tasks

The tasks in the data set were relatively simple. Task complexity as measured by a scale from 0 to 100 varied from 2% to 67.4%, the mean being 27%. Complex tasks were performed more seldom than simple ones: half of the simple tasks were performed weekly and 85% of complex tasks were performed every month or less frequently. Semi-complex tasks were performed quite evenly weekly, every month or more seldom. None of the tasks were reported to be performed on a daily basis.

The participants' work roles affected task complexity in quite a straightforward way: administrative staff performed most of the simple tasks and planners most of the complex ones (see Figure 1). The differences were statistically significant (Pearson X^2, p=0.002).

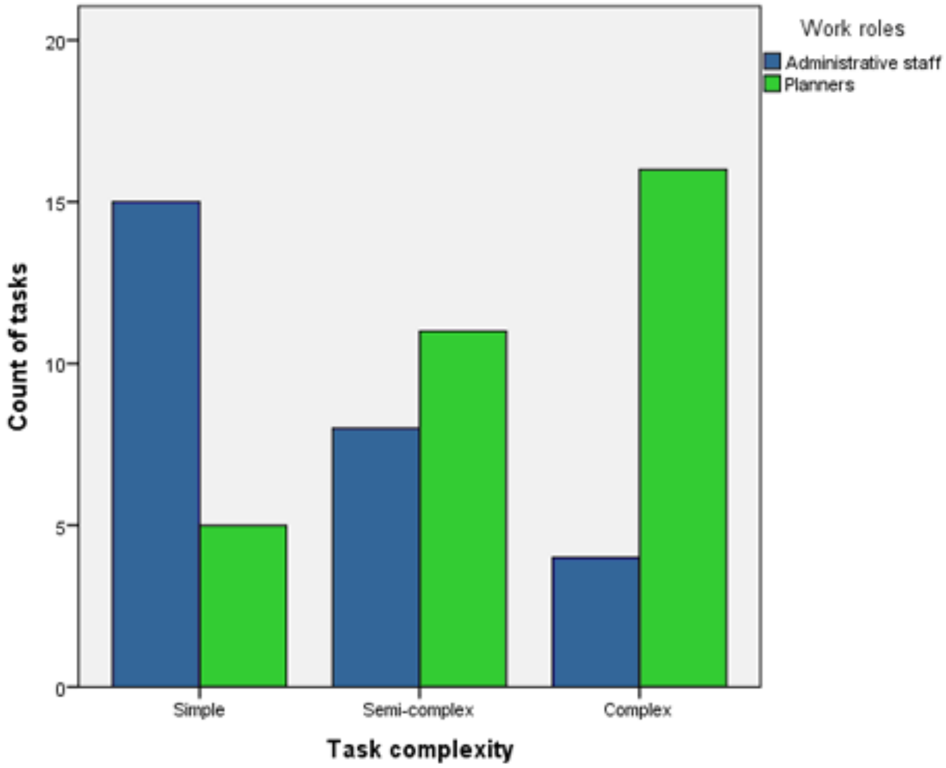

Figure 1: Work roles and task complexity.

Differences in perceived task complexity resembled what could be expected based on participants' positions. This finding seems to support the validity of our combined complexity measure. The planning tasks contain many wild cards whereas the nature of administrative tasks is to be quite routine-like. Nevertheless, planners had to perform administrative tasks as well (such as applying for a leave) and not all the tasks of the administration were so called routine but demanded context-sensitive reflection (such as appraising the competence of deputy candidates).

In the task initiation forms the participants were enquired if their aim was mainly to get the task quickly out of the way, to get it well performed or if they are only satisfied with an excellent result. In the task finishing forms they were enquired if they were satisfied with the result (on a four point scale). These two were associated in an interesting way: the more ambitious the goal, the more satisfied the participants were with the result (Pearson X^2, p=0.009). On the other hand, task complexity did not have an effect on either the goal or the satisfaction. Some participants tended to be more satisfied with their task outcomes than others but the goals were independent of the task performer.

Information internality

Across all complexity categories, internal information was more popular than external. In total, only 20 % of expected information and 16 % of materialised information was external. The differences between the use of internal and external information, both in terms of expected and materialised use, are statistically significant at all task complexity levels (Wilcoxon, p=0.000-0.006). The participants expected that they would use less internal information (both absolutely and proportionally) in simple than in complex tasks (see Figure 2). The use that materialised was quite the opposite: the share of internal information was bigger in simple than in complex tasks. That is, internal information was insufficient to assuage their information needs in complex tasks unlike they expected. Deviating from that, the participants predict the share of the need for internal and external information accurately in semi-complex tasks. Interestingly, semi-complex tasks have a peak of both expected and materialised use of internal information being over 90 % on average (see Figure 2).

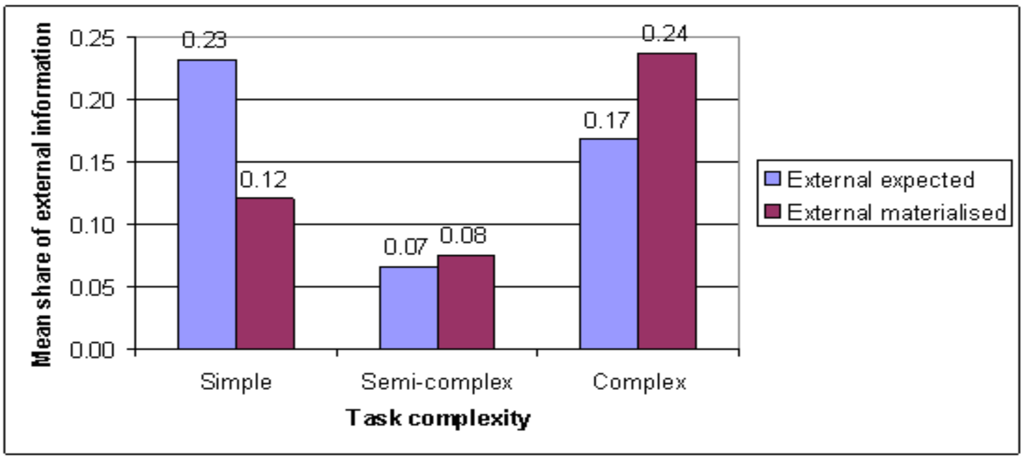

Figure 2: The mean shares of expected and materialised external information use in different task complexity categories.

In addition, the differences between the frequency of expected and materialised internal information use are statistically significant in simple tasks (t-test, p=0.021). That is, the expectations of usage of internal information differ most in simple tasks, which is quite surprising as simple tasks should be easily predictable by definition. Figure 3 illustrates the differences between the frequency of internal and external resources.

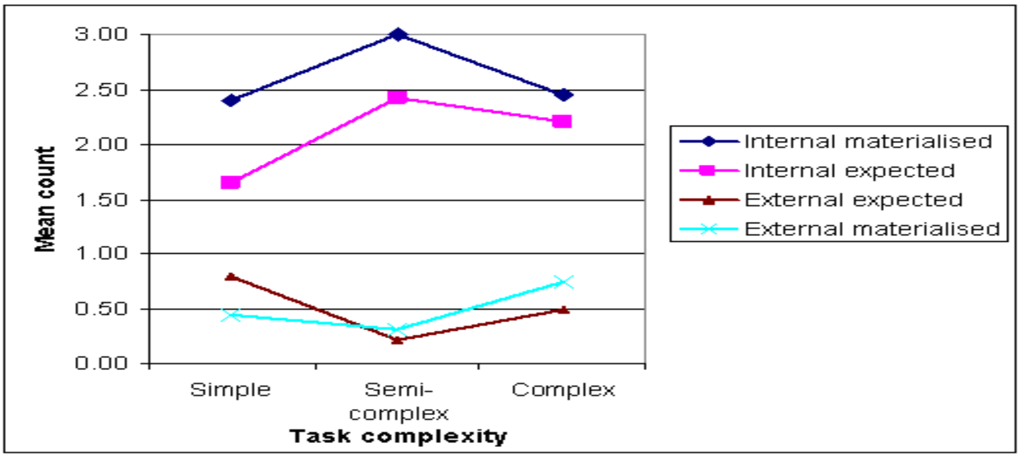

Figure 3: The mean count of expected and materialised internal and external resources.

In spite of the clear distinctions between the use of internal and external information, task complexity in itself does not appear to affect the internality substantially. It only affects the share of internality of materialised information use but the Pearson correlation of task complexity and information internality is only -0.26 (p=0.043). Consequently, the share of external information used increases a little with growing task complexity.

Internality of abandoned initial information. The more complex the task, the greater the amount of internal information that is abandoned during the task process, and the less abandoned external information, respectively. This means that, in simple tasks, less than 60% of abandoned information is internal, whereas in semi-complex and complex tasks over 90% of abandoned information is internal. The difference between the internal and external abandoned information (both absolutely and proportionally) is statistically significant in semi-complex and complex tasks (Wilcoxon signed ranks, p=0.004-0.020). The Pearson correlation between the share of internality of abandoned information and task complexity is notable (0.59) and statistically significant (p=0.004).

Internality of new, unexpected information. There tends to be a larger number of new external information needs in complex tasks than in simpler tasks. However, no such a clear linear trend holds for the number of new internal information. Proportionally, 83% of newcomers in simple tasks and 70 % of newcomers in complex tasks are internal, whereas 89% of newcomers are internal in semi-complex tasks. The difference between the internal and external newcomers (both absolutely and proportionally) is statistically significant in simple and semi-complex tasks (Wilcoxon signed ranks, p=0.002-0.021), but not in complex tasks.

Information types

Expected information types. Every information type is needed in tasks of every complexity category but the differences between different information types are really clear. Based on the participants' expectations, they would need most frequently facts in simple tasks and by far mostly information aggregates in complex tasks (see Figure 4). The differences between information types are statistically significant in complex tasks (Friedman, p=0.001), but not in other groups. Task complexity correlates significantly with the number of expected facts (Pearson's r -0.35, p=0.007) and information aggregates (Pearson's r 0.32, p=0.014). Task complexity also correlates with the share of facts (Pearson's r -0.41, p=0.001) and the share of information aggregates (Pearson's r 0.29, p=0.026). Subsequently, the more complex the task, the less facts and the more information aggregates are expected. Nonetheless, the differences between the use of known items in different complexity categories are not significant (Kruskal Wallis, p=0.186). Known items are most used in semi-complex tasks, and in complex and simple tasks they are used less but quite equally.

Dropped initial information types. Visually, it appears that the more complex the task, the smaller the share of dropped initial facts compared to all dropped information types (see Figure 4, right side). Nevertheless, neither the differences between information types nor between task complexity categories are significant. The expected use of information types and dropped initial information types are summarised in Figure 4/

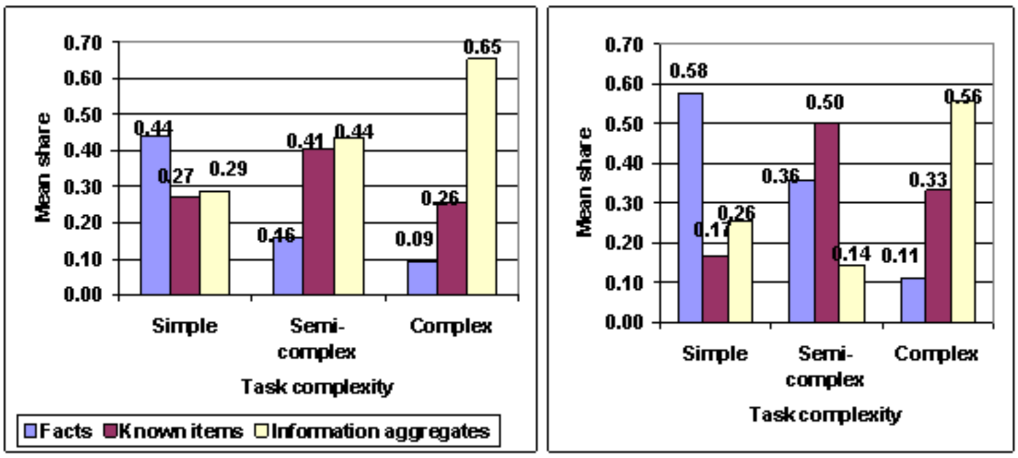

Figure 4: The share of expected use of information types (left) and dropped, initial information types (right).

Materialised information types. The materialised use of different information types looks in outline similar to the expectations of usage. In simple tasks, facts are the most used information type and they are used more than expected. In semi-complex tasks, known items have the greatest mean share of information types. As expected, information aggregates are the most used information type in complex tasks both proportionally and absolutely. The differences between information types are statistically significant in simple (Friedman, p=0.013) and complex (Friedman, p=0.012) tasks. As already seen in the usage expectations, task complexity correlates significantly with the number of facts (Pearson's r -0.37, p=0.004) and information aggregates (Pearson's r 0.30, p=0.022) used and with their shares of all information types used in an average task, respectively (Pearson's r for facts -0.47, p=0.000, and for information aggregates 0.37, p=0.005). Hence, the more complex the task, the more information aggregates and the less facts are used.

New, unexpected information types. Task complexity also correlates with the share of new facts (Pearson's r -0.44, p=0.006) and new information aggregates (Pearson's r 0.39, p=0.018) that are needed during the task process but not expected in the beginning of the task. Accordingly, the more complex the task, the less new factual needs emerge as growing task complexity indicates smaller need for facts on the whole. On the other hand, in complex tasks all information aggregates needed cannot be accurately listed before performing the task. The materialised use of information types and unexpected information types are summarised in Figure 5.

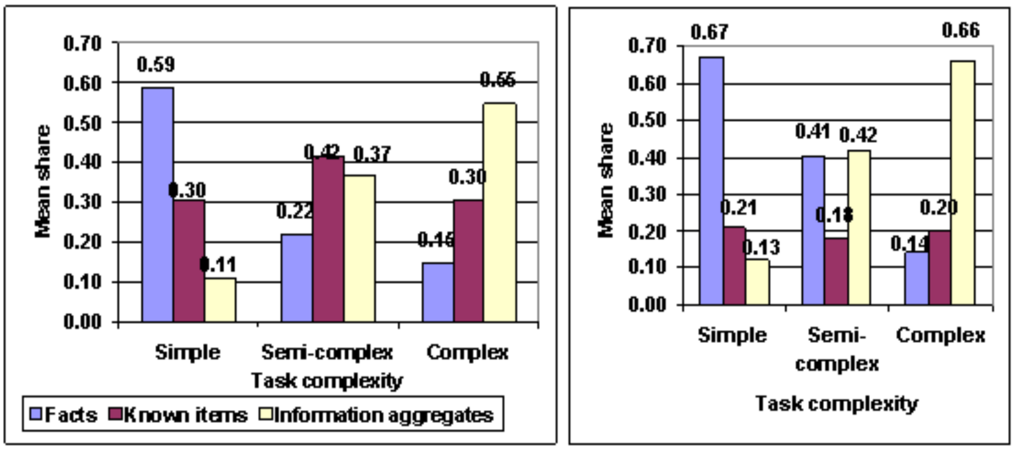

Figure 5: The share of materialised information types (left) and the share of new, unexpected information types (right).

Information type complexity. We found that task complexity correlated with information type complexity both before and especially after task performance (Table 1). It follows that the more complex the task, the more complex the information needed.

Table 1: The correlations between task complexity and information type complexity expected/materialised.

	Weighting of facts, known items, and aggregates					
	1-1-1		**1-2-3**		**1-5-10**	
Task complexity measure	**Expected**	**Materialised**	**Expected**	**Materialised**	**Expected**	**Materialised**
Continuous	0.09 P	0.21 P	0.30* S	0.48** S	0.34** P	0.50** P
Categorical	0.12 S	0.26* S	0.31* S	0.51** S	0.33* S	0.54** S

*=correlation is significant at the 0.05 level; **=correlation is significant at the 0.01 level; P=Pearson correlation; S=Spearman correlation.

Task complexity hardly affects the number of different information types needed in a task. Instead, task complexity is obviously connected to the ascending information type complexity on ordinal scale. If known items and information aggregates are weighted heavily in comparison to facts, the correlation is even stronger.

Accessibility and sufficiency. Information needs were not as well satisfied in complex as in simpler tasks. This is demonstrated by the differences between task complexity categories that were statistically significant both concerning accessibility (Kruskal Wallis, p=0.031) and sufficiency (one-way ANOVA, p=0.042) of information. On the whole, information was both easily achievable and sufficient but the differences between information types were significant (Pearson X^2, p=0.000). In other words, information aggregates were a little more difficult to find, and it was not so easy to obtain satisfactory information aggregates, either. On the other hand, facts were sufficient and found easily. Furthermore, the accessibility and sufficiency of known items were in between these two other information types.

Discussion

Tasks and their complexity

Participants' work roles affected task complexity: planners had more complex tasks than administrative personnel. The fact that work role did affect complexity demonstrated that the combined complexity variable was even objectively quite reliable as it handled complexity from many different viewpoints. Our results support what Leckie, Pettigrew and Sylvain (1996) state in their information seeking model: work role is a key factor affecting work tasks. They do not, however, explicitly refer to task complexity in their model. (Leckie *et al*. 1996).

Comparing tasks of different complexity across studies is challenging because of varying complexity criteria. Bystöm's (1999) categorisation is based on careful, qualitative analysis of several task features by the researcher; the complexity estimates of the participants played the major role but the final decision was on the researcher herself. These kinds of complexity estimates may be accurate but they are hard to repeat. Reading the representative tasks Byström (1999) gives, we can conclude that our simple tasks are mainly comparable to her information processing tasks and our complex tasks to her decision tasks, respectively. Hence, simple tasks are quick to perform and recurrent, and more complex tasks require creativity and they are longer-term projects. Though our classification is more influenced by the task performer, its simplicity makes it easy to appraise and apply.

Campbell (1988) emphasises the features of tasks at the expense of task performer's characteristics or opinion. He argues that the task performers' complexity estimates are at least indirectly influenced by task features, thus making the objective task traits more important. While we do not question such an influence, our classification is entirely founded on the task performers' views and it does not try to analyse the reasons for them. Either manner can be validated. However, if task features are to be evaluated by the researchers, they have to have a deeper insight into the substance of the tasks studied in order to classify them accurately. Additionally, Campbell's (1988) categorisation is not purely hierarchical. His complexity categorisation incorporates different sources of complexity and different task types producing a three dimensional classification that is not easily comparable to one-dimensional task categories.

Kumpulainen and Järvelin (2010) have a slightly different view of tasks, as they actually estimate complexity (the amount of prior knowledge) for data collection sessions that approximately equal tasks. This approach is practical and avoids the problem of defining the boundaries of tasks. Session complexity is determined by the researcher on the spot and therefore Kumpulainen and Järvelin's (2010) complex tasks may differ from ours although the knowledge to be estimated is partly the same. Their complexity estimates are also rigid in the sense that the participants either have the prior knowledge concerning the task or not, as judged by the researcher. We measured knowledge and complexity on a sliding scale and only afterwards applied a suitable classification scheme. This course of action had the advantage of both using the unclassified complexity estimates and enabling reclassification if needed.

Information internality

In our data, participants used mostly internal information despite of task complexity. Byström (1999) studied the same organizational setting and she found out that source internality depends on both task complexity and source type: the more complex the task, the more probable that internal people are used as sources and on the other hand, slightly more external documentary sources are used in complex than in simple tasks. We instead found that more use of internal information is expected in complex than in simple tasks, while more external information use is materialised in complex than in simple tasks. Herewith the expectations were the opposite of materialised use in terms of information internality.

One explanation could be that in simple tasks, the participants can easily name beforehand the prospective pieces of information, including external information whether needed in the performance of the actual, single task or not. As a case in point, a participant informed needing the administrative law in a routine task. It proved that she did not consult this law because she knew it already and thus did not report using it in the end of the task, either. Yet in case of complex tasks, especially the prospective external information is difficult to know beforehand and the participants itemise the familiar, i.e. internal information. We could even argue that the complexity of information seeking and vague information needs affect task complexity.

Information types and task complexity

Our categorisation for information types was grounded in the data. We did not apply any ready categories on information types used in a task. For this reason, comparing Byström's (1999) empirical results on information types to ours is only indicative. Our information types (facts, known items and information aggregates) are based on the extent or technicalities of information, whereas Byström's (1999) types (task, domain and task-solving information) are more based on the contents of the information object. With caution and to a limited extent we could argue that *task information* is similar to facts and *domain information* similar to information aggregates, because facts are often needed only in a limited task context and information aggregates can more easily be applied in a broader one, as well. *Task-solving information* is not applicable to our classification.

Information type use is clearly dependent on task complexity. The more complex the task, the more information aggregates and the less facts are needed. Equally, Byström (1999) found that information types are used in a certain order of importance when task complexity increases. Only narrow information is needed in simple tasks, additionally broader information in more complex tasks and even task-solving information in the most complex tasks (Byström 1999).

In our data, known items were used evenly in all task complexity categories. This may be due to the nature of known items; they are used for many different purposes from searching facts to understanding a topic (assumed to be found in a certain known-item) or from reading software manuals to delivering official records. A known item may be needed for example if all information in it may be useful (e.g., if a participant mentions a certain book title but does not refer to the purpose of use), or when a certain piece of information must be forwarded or handled regardless of the contents (e.g., filing records). A known item can be even both: a person may be told to (a) find a document (*known* item) to share as a copy (e.g., by e-mail) to some group of people (e.g., meeting attendees) and (b) then study its contents carefully, as well, in order to chair a meeting, for example.

The above example demonstrates that participants may refer to a *known item* which can actually have diverse meanings that cannot be sorted out in a short questionnaire form, for example. This may be one reason for the need for known items not being affected by task complexity. It could be argued that a participant frames and names a piece of information or an information type so that it reflects her understanding of its most important parts or uses. It goes without saying that she does not use the same conceptualisations as researchers normally do. Known items were analysed as far as possible in this study but as we focused on the conceptualisations of the participants, we desired to avoid excessive reading between the lines. It should be noted here that known items fell into known item category because they could not be put elsewhere on good grounds. This happens because people may demonstrate their information use vaguely in a questionnaire.

We found that the more complex the task, the smaller the share of dropped initial and new, unexpected facts. We can argue that to some extent, there are so many initially needed facts especially in simple tasks that it is obvious that some of them are dropped during the task process, because a fact is such a small a unit that it is more difficult to predict accurately than information aggregates. On the other hand, in complex tasks, almost 60% of dropped initial information types are information aggregates. This notion is more difficult to explain. For some reason, information aggregates tend to get switched in complex tasks as easily as facts in simple tasks, as information aggregates are also by far the most frequent new, unexpected information type in complex tasks.

Another important finding was that the more complex the task, the more complex the information needed. This result is consistent with those of Bystöm (1999). However, our study has been unable to demonstrate that the more complex the task, the more various information types needed, which was one of Byström's (1999) main findings. This is because we had different information type categories. It seems evident that people may use both task information and task solving information in a non-routine task (Byström 1999) whereas it is unclear to what extent separate facts are needed in complex tasks in addition to information aggregates. Of course they might be needed but it is not a special feature of complex tasks compared to more simple ones.

We also analysed how easily different information types were found and whether they were sufficient to satisfy the participants' information need. Differences between information types were statistically significant. Facts were well accessible and satisfactory, whereas information aggregates were more taxing to find and less satisfactory. Known items fell in between these two on both dimensions. These findings are quite obvious if we think about the nature of these two information types. Facts are easily definable and may be one or two words long; information aggregates are substantial units of information and their boundaries more difficult to delimit.

Methodological discussion

Once we had got the research permission from the city, we were not able to affect the way the participants were selected. Hence, no statistical sampling methods were used, whatsoever. The participation was voluntary and gratuitous on behalf of the participants. Arranging the sessions in concert with the participants was a necessary precaution for successful data collection as the work situations were authentic. Therefore the participants were allowed to decide the dates of data collection sessions. Accordingly, we had a convenience sample of fifty-nine tasks. This may have affected the features of the tasks. For example, the tasks may have been unusually simple because the participants wanted to manage well their work observed in the study. On the other hand, we had several, hours long sessions with each participant and thus it is unlikely that the participants were able to play some role the whole time or to select all their tasks.

The participants completed an electronic questionnaire form in the beginning and end of each task performance. This method worked well: the participants commenced to remember to complete the forms without request quite quickly and we believe that they did it carefully because they knew the researchers. This would not have been possible if we only used a questionnaire to obtain several hundreds of participants. We also saw that information seeking is such diverse a phenomenon that a single questionnaire cannot yield a thorough overview.

The limitations in the present study include the small data set. We had only fifty-nine task initiation and end form pairs but this small amount was due the fact that the data had been initially collected to be used in combination with the shadowing data (see Saastamoinen *et al*. 2012). We did not aim at statistical generalisability because our data set was too small and the study was not designed for that, either. However, as the participants committed themselves to shadowing and got acquainted with the researcher, it is probable that they were more motivated in completing the forms carefully than if the researcher had been anonymous or vaguely known.

Unfortunately, some of our questions were formulated ambiguously and thus the answers could not be reliably compared. However, it was more common that there was insufficient variation in the answers to compare the task complexity categories.

Conclusions

The notion of context has grown increasingly important in information studies. Tasks and their features have proved a useful context especially for work related information seeking as work usually consists of several tasks of different topics and complexity. This research examined information use related to the work tasks of a city administration. This study revealed the quantitative differences between information type use in simple, semi-complex and complex tasks and between expected and materialised use.

The results of this study indicate that a maximum of approximately a fourth of information types used are external. External information is used the least in semi-complex tasks where its share is only under 10 %. Surprisingly, participants were found to expect using more external information in simple than in complex tasks though they actually used more external information in complex tasks.

On the question of divergent information types, this study found that participants used three separate information types, namely facts, known-items and information aggregates. The use of facts clearly declined with growing task complexity, whereas the use of information aggregates increased. The use of known-items seemed independent of task complexity. Use expectations were well met in materialised use.

These findings have potentially important implications for developing information (retrieval) systems to support various work tasks. Well performing information systems can assist in any task but it is especially significant to understand the differing information needs in simple, semi-complex and complex tasks. Present systems are often designed for mainly factual information needs or otherwise simple task processes. This study confirms that the more complex the task, the more complex the information need and information use; thus flexible repositories and information systems are also needed to reinforce performing complex tasks.

Though the tasks and their features analysed in the study may not be a representative sample, we offered a simple task categorisation method that is easy to apply and that proved useful in the present setting. This kind of rough classification based on mere numerical estimations may miss some positive effects gained from qualitative task analysis but it facilitates comparing the tasks and findings across studies.

Our data must be interpreted with caution because we had a relatively small data set collected through questionnaires in a limited context and time frame. Thus more research on this topic needs to be undertaken. In addition to the information types, it is important to study the sources where information is searched for and/or found in different task complexity categories. Using several data collection methods concurrently (triangulation) and conjoining the data for analysis should improve the reliability and generalisability of results in the future.

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Appendices

Appendix 1: Orientation form (translation, original in Finnish)

Contact information
Name:
e-mail address:
Telephone number:

Background information
Your official job title:
Are you in a supervisory position?: Yes/No
The highest educational degree you have completed:
The other most important studies related to your work and their extent or duration (e.g., "Skills needed in work" -course, 1 year and 2 months).:
How long have you been in your present work in the present position or equivalent (e.g., 1 year and 2 months)?:
Your responsibilities:

Work tasks
How varied do you find your tasks?: Very similar/Similar/Varied/Very varied
Think what kind of task types you can recognise in your present job. Please describe some of them briefly.:

Sources
Which information systems and information sources do you normally use in each work task you mentioned above?:
What information do you search for in each source you mentioned above?
Does some specific information system or information source facilitate your work especially? How?:
Do you find it difficult using a specific information system or an information source? Which one? What kind of problems have you encountered?:

Appendix 2: Task initiation form (translation, original in Finnish)

Please answer these questions based on your task at hand before you commence performing it.
Background information
Your name:
Describe the task:
What is your role in performing the task?:
How often do you perform similar tasks?: Daily/Weekly/Monthly/More seldom

The beginning of the task
Estimate how complete the task was when you got it (%):
How well does your expertise match the know-how needed in the task? (0="All in this task is totally new to me!", 100="All in this task is totally familiar to me!"):
How complex does the task appear to you? (0=really simple, 100=really complex):

Performing the task
Describe factors independent of you that may affect performing the task:
Estimate how well you know the task stages beforehand (0=the task is still utterly strange; 100=I know exactly the stages needed):
What information sources or systems do you think you are going to use when performing the task?:
What information do you seek in these sources?

Outcome
What is your ambition level concerning the task?:
- I want to get rid of it as soon as possible.
- I desire to win it done well.
- I'm satisfied only with a really good result.
- None of the above mentioned (describe in the next field).

Your ambition level in your own words:
How precisely do you know the outcome of the task? (0=I do not know the outcome at all, 100=I know exactly what the outcome should be like):
Describe the task outcome as accurately as possible:

Appendix 3: Task finishing form (translation, original in Finnish)

Please fill in at the end of work task performance.

Background information
Your name:
Work task completed:
Date of beginning the task:
At which stage of the task did the shadowing take place?: In the beginning / In the middle / In the end
How large a share of the task performance did the shadowing encompass (%)?:

Satisfaction
How satisfied are you with the task result?: Really satisfied / Satisfied / Neutral / Unsatisfied / Really unsatisfied
Why are you / are you not satisfied?:

Which sources did you use?
(In two columns the answer should be on a scale of one to five; 1=totally disagree, 5=totally agree.):

Source	Information sought	Info. was found (1-5)	Info. was adequate (1-5)
1			
2			
3			

...(cells up to row 7)

Were there any problems during task performance in information seeking or using material? What kind?:

Other
How complex was the task? (0=really simple, 100=really complex):
Here you can provide any extra information concerning the task or the answers you gave:

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Expected and materialised information source use by municipal officials: intertwining with task complexity

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Abstract

Introduction. This paper examines information seeking in a city administration. We analyse the relationship between information source use and task complexity, and the connections between sources and information types.
Method. Data were collected through pre-task and post-task questionnaires completed by six city administration employees during their normal workdays. The data set was collected on fifty-nine tasks chosen by the participants.
Analysis. The pre-task and post-task forms of the same underlying task were joined together and each task was assigned an aggregated complexity estimate based on the estimates made by the participants. Expected (pre-task) and materialised (post-task) information types and sources were classified and finally, quantitative analysis methods and statistical tests were used to find trends in information source use by task complexity.
Results. Five information source types (the Web, organizational information systems, e-mail, human sources, other) were recognised in the data. Task complexity affected the use of some sources more than others. Increasing task complexity reduces the use of organizational information systems and increases the use of Web resources, respectively.
Conclusion. We found that task complexity is an important factor explaining information seeking behaviour, and specific source types are used when seeking for specific information types.

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Introduction

People often need to seek for information in various information sources to perform both work and leisure time related tasks. Information seeking is an integral part of tasks and, therefore, task traits direct information seeking. Thus tasks and information seeking intertwine and should be studied in tandem in order to understand tasks' effects on information activities.

Empirical information seeking studies have a long history in which information needs and uses in different environments are analysed. The literature contains several theoretical information seeking models, such as those of Paisley (1968), Allen (1969), Dervin (1983) and Kuhlthau (1991). Paisley discusses different social groups and institutions that affect a person's information seeking behaviour to various degrees. He arranges the factors into a system of concentric spheres. The factor that affects the most is at the centre; that is the information seeker's personality. Allen revises Paisley's model by stating that the effects of social groups, or their strength, on information seeking behaviour are not static. Dervin suggests in her sense-making approach that information seeking is gap-bridging after encountering a problematic situation. Kuhlthau presents six phases of the information seeking process; each phase involves characteristic thoughts, feelings and actions.

It is less common to analyse tasks as variables in an information seeking study. The task aspect may be ignored (Ibrahim, 2004; Taylor, 1968) or, more generally, the whole study is focused on information seeking in one task type, such as everyday problem solving (Savolainen, 2008), searching for health information (Harris, Wathen and Fear, 2006) or the process of writing a dissertation (Kallehauge, 2010). Even Kuhlthau's classic model of information search process was originally based on information seeking of students writing a term paper (Kuhlthau, 1991). Task classifications in several studies concentrate on only a few specific task types that are difficult to generalise to other environments (for example Du, Liu, Zhu and Chen, 2013; Serola, 2006; Kwasitsu, 2004). Task complexity is a task feature that can be conceptualised to support generalisation. The concept of task complexity is discussed by, for example, Li and Belkin (2008), Campbell (1988) and Vakkari (2003). It has also gained attention in some empirical studies: Byström and Järvelin (1995) and Byström (2002) found that task complexity was clearly connected to information source use. Hansen (2011) connects task complexity to different task types. Kumpulainen and Järvelin (2010) and Saastamoinen, Kumpulainen and Järvelin (2012) discuss task complexity based on empirical research. We still need more information about how tasks affect information seeking because the fact that information seeking happens only for a reason and in a meaningful context, should not and cannot be ignored. Understanding the real work context, where the sources are used, is a key factor in understanding information behaviour and further developing more appropriate information systems.

In this study, we analyse the use of information sources in the context of varying task complexity and from the perspective of task performers. Participants were asked to estimate task complexity with several variables and report the sources they were planning to use and the ones they finally used. The participants were allowed to name the sources freely, and the researchers formed a suitable source categorisation afterwards.

The present study uses Byström's (1999, 2002) work both theoretically and methodically. We also share a common organizational setting. Therefore we discuss Byström's study throughout the paper, and in the discussion section our findings are compared to hers. Moreover, the temporal difference enabled a comparison of current city administration with that of the mid 1990s when Byström's data was collected.

The findings in our two earlier papers (Saastamoinen *et al.*, 2012; Saastamoinen, Kumpulainen, Vakkari and Järvelin, 2013) are based on the same research project and data set. However, they all have distinct contributions that do not fit in a single paper. The first paper (Saastamoinen *et al.*, 2012) discussed the findings based on observation data; information source use, information retrieval and problems the researcher observed while the participants performed their work tasks. The second paper (Saastamoinen *et al.*, 2013) studied the expected and materialised information types (information aggregates, facts, known items) based on questionnaire data. The present paper concerns the questionnaire data, as well, but the focus is on the information sources (human sources, organizational information systems, the Web, e-mail, other sources) the participants used. Different literature and theory are discussed in the two papers, respectively. Presenting all findings of the research project and the versatile data set in one paper would have been impossible both in terms of length and readability.

The specific research questions for this study are:

- Which information sources are expected to be used at task initiation and which information sources are dropped during the task process?
- Which expected information source uses are materialised and which information sources are discovered only during the task process, that is new, unexpected sources?
- How does task complexity affect the expected, dropped, materialised and new information sources?
- Which information types are sought for in different information sources?

The research questions are answered by analysing questionnaire responses concerning fifty-nine tasks of city administration professionals. We take a quantitative approach to the analysis, and shed light on information source use in real-world tasks of varying complexity.

Literature review

A task is a sequence or a group of activities that are performed in order to attain a goal, that is an outcome (Vakkari, 2003). Task traits affect the information seeking process (Leckie , Pettigrew and Sylvain, 1996), and especially task complexity is an important factor (Byström, 2002). Though acknowledged and discussed as a task feature, task complexity does not have a common definition among researchers. (See Saastamoinen *et al*., 2013 for a more thorough discussion about tasks and task complexity).

Information sources are the means of information seeking, and the bridge between information needs and information use. The theoretical concepts of information needs, seeking and use have been widely discussed in information studies literature (e.g. Case, 2006; Ingwersen and Järvelin, 2005), whereas the more concrete concept of information sources has often been regarded as a simple truism. We argue that information sources are theoretically interesting instruments of the information seeking process. In many studies, the theoretical reasoning behind the source types chosen has been neglected although the types reflect the study itself on a meta level (if the data are fitted into a ready-made source classification) and perhaps more importantly the phenomena studied (if the classification is based on the data). Thus the information sources missing from the data are as important as the ones observed, for instance. Common grounds for information source analysis would facilitate comparing studies and hence accumulating knowledge in information science. However, this does not indicate that we should invent a single, all-purpose source classification. Instead, we should introduce and become conscious of the features of the sources and the classifications in order to compare the use of sources sharing similar features across studies. Next, we will propose some useful concepts for analysing information sources. We also give some examples of the use of these concepts in the literature.

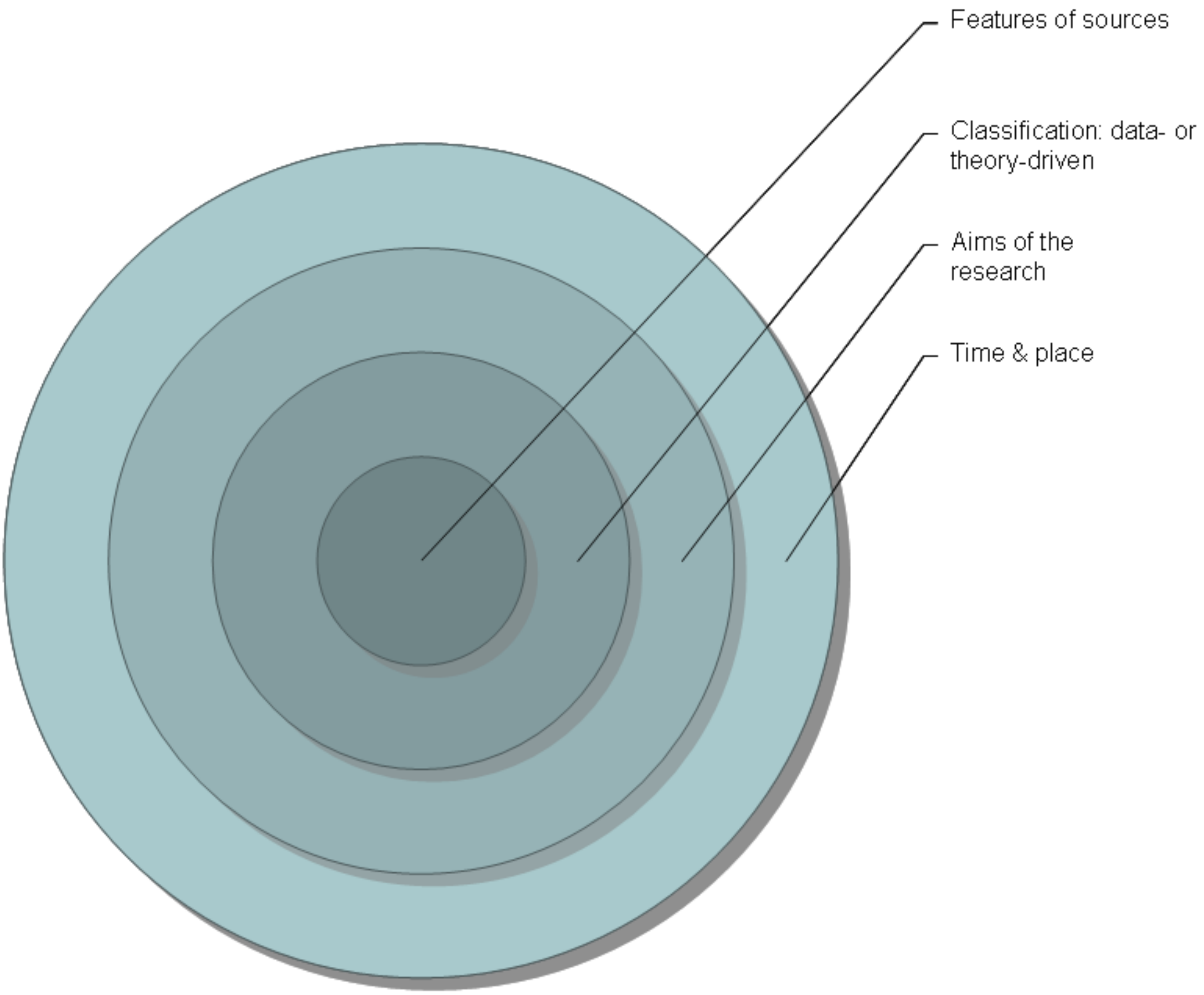

Figure 1: The foundations of features of information source classifications

Figure 1 distils the contexts that may indirectly affect the selection of features in classification of information sources. Time, place and aims of the research are inevitably defined before the source classification, and the classification is either data- or theory-driven.

Every research project is bound to its physical (temporal and spatial) context. A classification can hardly describe nor needs to describe the sources that have not yet been invented or are used little because of their novelty or antiquity. For example, Web sources and electronic data systems are considered to be more important in city administration contexts today (Saastamoinen *et al.*, 2012) than they were in the mid-1990s (Byström, 2002). The same goes for other contexts, too, such as libraries (Taylor, 1968 versus Ibrahim, 2004). The spatial context of research may be a country or a more specific place such as a rural area (e.g., Harris *et al.*, 2006), which may pose preconditions to the source classification. The place may still affect the classification, even if the spatial context is not an explicit variable in the study (which often is the case).

In addition to the physical context, research goals and questions in each study guide the ways how to construct the source classifications. For instance, work related information seeking studies include special sources needed in the named work context, such as the Web of Science and Google Scholar in the case of researchers (Nicholas, Williams, Rowlands and Jamali, 2010) and bio-databases in the context of molecular medicine (Kumpulainen and Järvelin, 2010). Everyday life information seeking studies are more likely to reveal generic, leisure time related sources such as friends and newspapers (Harris *et al.*, 2006; Savolainen, 2008). Work and everyday related classifications may be partly congruent at the surface level, as well. For example Babalhavaeji and Farhadpoor (2013) study library managers' environmental scanning, and in that context newspapers and broadcast media are relevant information sources for the participants. Thus the studied tasks (writing a paper, environmental scanning, treating one's own illness), whether work related or not, define the set of relevant sources. Task types may be a variable in a study (e.g., Du *et al.*, 2013), or they can be implicit whereupon the varying tasks are reduced to one task type, such as problem solving (e.g., Kallehauge, 2010).

Source classifications are either (mainly) data- or theory-driven. By data-driven we mean that the classification stems from the data contrary to theory-driven classifications that are ready-made before the data is analysed or even collected. Theory-driven classifications are naturally applied in questionnaire studies where the use of specific sources is under research (e.g., Morrison, 1993). Data-driven classifications are used in studies that focus first on the participants or the context of information seeking and only then try to analyse the sources used based on grounded theory type of methodology (e.g., Hansen, 2011). Seemingly, the basis of source classification may change from data-driven to theory-driven or vice versa during the research process. The researcher may begin to analyse the data to find meaningful classes and only then realise that a ready-made classification suits perfectly; or the classes used in a questionnaire prove useless and must be rearranged.

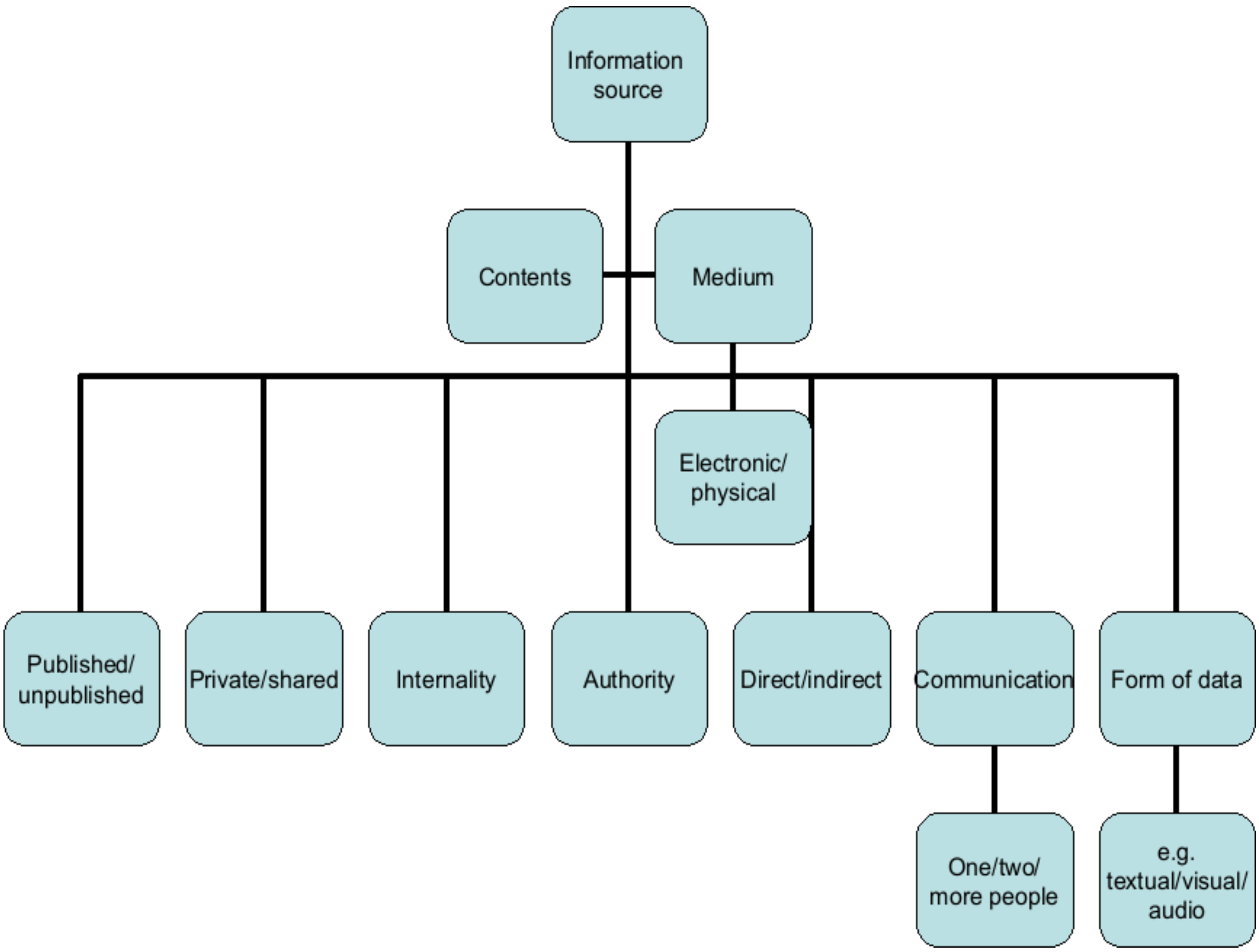

Figure 2: Aspects of information sources.

The information sources themselves are characterised by eight facets that describe them (see Figure 2). The facets are:

1. content vs. medium;
2. published vs. unpublished;

3. private vs. shared;
4. internal vs. external;
5. authority;
6. direct vs. indirect;
7. communication; and
8. form of data.

All of these facets may not be applied to all sources at the same time but various studies and categorisations emphasise them differently. Firstly, all information sources are labelled by either the contents or the medium (1) of the information object. This is an inevitable feature of all sources. Contents are a type of information objects that are named without binding them to a medium but that are still regarded as sources, not information types in a classification. For example Hansen's (2011) classification has some sources of type *medium*, e.g., Web sites and online articles. In the empirical domain of his research, patent engineering, Hansen also has content based source classes, such as bibliographic information and classification code schemata.

If a source is of type medium, it must either be electronic or physical. This feature is not applicable to content labelled sources because bringing the aspect to a content actually makes it a combination of both the content and the medium (for example *electronic minutes*). The classification of Chowdhury, Gibb and Landoni (2011) exploits the medium perspective: they itemise only electronic sources (called digital), e.g., e-journals and e-books. One possible medium type is physical sources including all kinds of papers (Saastamoinen *et al*., 2012) and printed sources (Savolainen, 2008).

Secondly, published and unpublished (2) sources can be separated. This feature is related to the third facet, private and shared (3) sources. Books are published sources but they may be part of private collections. Private (personal) collections are separated from other sources for example in the classifications of Chowdhury *et al*. (2011), Kwasitsu (2004), and Taylor (1968). One's own observations or memory are also private sources as distinguished by, for example, Kwasitsu (2004), Taylor (1968), and Morrison (1993). Shared sources are the opposite of private sources meaning that they are potentially shared with other people and not privately saved on one's own personal computer, for example.

Many classifications discriminate internal and external (4) sources, resembling the separation between private and shared sources in a larger scale, often regarding an organization. However, there is not just one correct use of the concepts of internal and external; they must be defined again in each study. Naturally, external sources are notably different from internal ones though their boundaries may differ across studies. Internality may also involve all sources, only some of them, or the internality can be judged afterwards based on implicit assumptions though not considered in the initial classification. Du *et al*. (2013) separate internal and external sources, as well as Kwasitsu (2004) and Babalhavaeji and Farhadpoor (2013). However, unlike Byström (2002), they have different sources in external and internal classes. Byström's classification is on a more abstract level and thus all her sources, with the exception of visits and registers, have internal and external counterparts (e.g., people concerned in the matter at hand and literature). She judges internality by the location of the source. There are two alternatives, inside or outside the organization. Another perspective to internality is the place of production of the information content of the source (Saastamoinen *et al*., 2013).

The fifth facet concerns the authority (5) of a source. This aspect is seldom explicitly stated in source classification but in a research setting some sources are often more authoritative than others. This may concern the legal status of a source or other social ways of justifying the use of a source. For example Guo (2011) specifies several implicitly legitimate sources of information in the context of new product development including suppliers and collaborating organizations. Guo's classification of the sources is pre-made for a questionnaire. Because of the field Guo studied, it is understandable that his classification automatically excludes unauthoritative sources such as a doctor or friends. On the other hand, a doctor may be a self-evidently important and legitimate source in a different context, that is, when searching for health information (e.g., Harris *et al*., 2006).

Sources have been defined as carriers of information content (Ingwersen and Järvelin, 2005; Byström, 2002). Case (2007) however argues that this application of the term source is actually incorrect. According to him, a source is the primary producer of information, for example the author of a book and the book should be called a channel. A channel may be understood as a broader concept, as well as a medium giving access to sources (Boyd, 2004; Byström, 2002; Serola, 2006). For example libraries, reference books or people can act as channels in this respect. As the relationship of these two concepts is somewhat complicated and equivocal, we only apply the term source for simplicity. The source or channel question may be the sixth facet, which will be called here direct and indirect (6) sources. Direct sources, such as printed journals in Jamali and Nicholas' classification (2010), provide the information needed directly. Of course arguments may be made against this perspective, depending on the use of the source in question. A printed journal may be browsed in order to attain new references. Jamali and Nicholas have a separate class for reference lists so a journal is obviously a direct source in their study: searching Google is one option to identify relevant articles in their questionnaire. Google may be regarded as a direct source if the information needed is already present in the snippets of the result list; that is if the list in itself satisfies the information need. In many cases, a search engine is unlikely to provide the information right away, providing as it does a list of links to potentially useful Web pages in response to a search. In this sense, Google may rather be described as an indirect source in terms of our classification. Xie and Joo (2012), Kumpulainen and Järvelin (2010) and Chowdhury *et al*. (2011), among others, separate search engines and single Web pages in their classifications which reveals the underlying aspect of directness.

Communication (7) between people is regarded as a special way of seeking information in many studies and thus it is our seventh facet. If communication is recognised as a source in a classification, it may be done by emphasising the contents of the communication or communication tools. This returns to our first facet common to all sources, the separation between contents and medium. However, contents in the context of communication may be interpreted as the people to be communicated with (friends, a doctor) compared to media (e-mail, mail, telephone, etc.). Many classifications also recognise meetings and/or institutions as sources alongside individual people. Guo's (2011) classification of sources in product development is oriented toward organization and people, having categories such as competitors and university. Koo, Wati and Jung (2011) study the use of communication technologies and accordingly their information sources are communication tools: blogs, e-mail, telephone, video conferencing and instant messenger. Wilson (1981) makes a classic grouping of information sources to formal information systems in a broader sense than only on-line services, other information sources and other people. This grouping stresses the importance of human sources and the role of, as Wilson calls it, the information exchange that happens between people. A similar division is made by Hansen (2011) between paper, electronic and human source types.

The last source facet concerns the form of data the source provides (8). The data may be for example textual, visual, audio, raw data or programming code (or any combination), sometimes also confusingly called media or content. The division between forms of data is seldom explicit in source classifications but it still exists. Textual data may be assumed as a default when a category such as the Web is formed. However, communication is often a natural application of audio data, and talking to a person may differ from, for example, sending e-mail, in that one can express oneself and react quickly. Therefore some classifications break the communication category down to the level where face-to-face interaction can be identified (e.g., Saastamoinen *et al*., 2012). Source classifications in general do not analyse, for example, whether a book is used to attain text or images; perhaps because a picture is more often considered as an information type than as a source. However, an opposite view can be fruitful. For example Hansen (2011) found that images played an important role as a source in patent professionals' information seeking. Furthermore, Serola (2006) discovered a source type of direct observation where city planners went to actually see the place they were intending to plan. They photographed the scene to make the information tangible, which seems to parallel the function that images of inventions have for patent professionals. Both far-reaching planning of city areas and deciding for patents need tangible, visual information. This point of view differs from what Lloyd (2006, 2010) refers to as physical or corporeal information.

Corporeal information is gained through acting in a situation (such as fire fighters in the case of extinguishing a fire) and watching others acting. Thus, this intangible and often implicit information is the opposite of Lloyd's textual information because the former cannot easily be documented. Lloyd does not make a distinction between text and images, as they are both a type of formal information. It cannot be denied that people do gain a lot of information by acting in the world themselves. However, this action may rather be called learning than an information source in the context of information seeking studies. If defined through more tangible source features, corporeal information means actually using human sources; one's own self or other people (in our classification direct private communication, probably both visual and audio information). Lloyd has a category for social information as well but it relates to forming a '*shared view of practice*' (Lloyd, 2006, p. 575). Moreover, Lloyd uses the concepts information and information source quite interchangeably.

Byström (1999) has an information source category similar to corporeal information, namely visits as sources. However, these visits are rare in her data and they seem more equivalent to photographs: visits are clearly defined inspections to the places in question, not implicit information gaining by doing one's work.

Figure 2, above, distils the features of information sources that were discussed above. The feature of content or medium is the most crucial one in the sense that it is compulsory by definition; one would not have a source at all unless it is either contents or a medium. Combining other features forms divergent information source types presented in information seeking studies. A single source in a classification may be loaded with all of the features or just a few. In general, it may not be possible or appropriate to analyse all of them for all information sources in one study. However, differences and similarities of information sources should not be taken for granted. For example, sample questions might be: Does television differ from newspapers as a source and how? Is a different source being used when talking to a person face-to-face instead of sending an e-mail? What is the added value of printouts compared to electronic records?

The classification features presented in Figure 2 and discussed above are intended as components of a generic classification of information sources. In the present paper, we introduce a data-driven and medium-based information source categorisation that portrays our empirical findings and raises the abstraction level of individual sources. The categorisation is presented in the next section, and the consequences to the interpretation of our findings are reflected in the discussion section.

Study design: participants, methods, and data

The participants were a convenience sample of six administrative employees of a city of some 200 000 inhabitants. All participants worked in the central general administration of the city. They were recruited by an internal agent of the city, and the participation was voluntary. Participants were not offered any compensation for their participation. We had two main data collection methods, namely observation and two task specific questionnaires, one to be filled in at the beginning of each task and the other when finishing it (for detailed questionnaire forms, see Appendices). The results of the observation are discussed in Saastamoinen *et al*. (2012) while information type use and the features of the studied tasks are more thoroughly presented in Saastamoinen *et al*. (2013). The present paper covers the results of information source use based on the questionnaires.

The data set consists of fifty-nine tasks consisting of task initiation and task finishing form pairs. In the questionnaires, the participants were asked to list the information sources and information types they were planning to use and the ones that were used. Each task was set a complexity value. Task complexity was defined as the average of five task complexity components, namely 1) task complexity estimated in the beginning and 2) in the end of the task; 3) the task performers' expertise; 4) their prior knowledge about the task process; and 5) their prior knowledge about the information needed in the task. All of these were estimated by the participants themselves in the questionnaire forms. The internal consistency (Cronbach's alpha) of the composite measure was 0.79 (confidence interval 0.69-0.87). Task complexity varied between 2 % and 67.4 %. The continuous task complexity was also divided in three complexity categories, simple (20 tasks, complexity ranging from 2 % to 18 %), semi-complex (19 tasks, complexity ranging from 18.75 % to 32 %) and complex (20 tasks, complexity ranging from 33 % to 67.4 %) for most statistical tests and to facilitate the interpretations. In other words, task complexity was used both as a continuous and as a categorised variable.

Our conception of complexity applies Byström's (1999, 2002) ideas of task complexity as the degree of a priori knowledge concerning a task at hand. Similarly, we asked about task complexity directly ('How complex is the task?') in addition to *a priori* knowledge, and the participants estimated the complexity without any interference of researchers. Thus our task complexity is purely subjective. Because Byström (2002) in her study examined the same city administration that was examined in this study, her methods were used to enable temporal comparisons.

In contrast to the method used here, Kumpulainen and Järvelin (2010) have used a similar task complexity measure. They asked the participants to describe the task so that the researcher was able to estimate the degree of *a priori* knowledge of the task performer. Their complexity estimate was based on the knowledge the participant could present rather than on the gut feeling of the participant. Thus the complexity measure is reliable as the researcher evaluates all tasks against the same criteria.

Every information source in our data set was classified as human sources, e-mail, the Web, organizational information systems or other sources. These rough classes were reliably identifiable in the data; thus the classification is data-driven. Only the medium, not the content, were taken into account. Similarly, all source types can be used to attain information either directly or indirectly. In principle, organizational information systems are the most authoritative sources. Human sources and e-mail can be regarded as communication channels though they belong to different classes (see below).

For the purposes of this study, human sources is defined as the people and organizations that are mentioned in the forms without a reference to a medium. That is, the participants were not necessarily in contact with them face-to-face but they felt that the person mentioned, not the medium of communication, acted as a source. A few times an organization was mentioned, as well, and these cases fell into this category as no medium was mentioned, and as one can contact only a contact person rather than the organization as a whole. E-mail composes a class of its own because simply naming "e-mail" as an information source was quite common among the participants. All employees in the target organization used the same e-mail client. E-mail was used both as a communicational channel and as an archive for important messages and files.

The difference between the Web and organizational information systems in the classification is that the Web is publicly available on the Internet without a fee, and organizational information systems have restricted access. For example, a Web search engine is part of the class the Web, whereas business management software and internal databases are organizational information systems. In the case of a Web source subject to a charge, it was regarded as an organizational source as it would not have been used without the support of the organization. The last class, other, contains only a few instances that cannot be put elsewhere on good grounds, such as printed books.

Information types were classified as well in order to analyse if sources were used differently with respect to information types. (A more thorough analysis of information types is presented in Saastamoinen *et al.*, 2013.) The classes are facts (e.g., a name), known items (e.g., the record of yesterday's meeting), and information aggregates (larger themes, e.g., the state of municipal health care). The classes were purely based on questionnaire answers. For example, if a known item was mentioned, we did not guess further whether there might have been a useful fact in the known item. A piece of information was a known item only if it clearly was not either a fact or an information aggregate.

We calculated the expected and materialised source use, and the number of dropped initial and new, unexpected sources. Expected sources are the ones recorded in the task initiation form, materialised sources the ones in the task finishing form. Dropped initial sources were expected to be used but not mentioned in the end; and new, unexpected sources (*newcomers*) were mentioned in the end but were not expected, respectively. Newcomers and dropped sources required reasoning in their assessment. They do not represent just remainders of expected and materialized sources, as the participants may often express the sources ambiguously. Hence, it was left to the researcher to judge the relationships between the information objects mentioned. In our case, only entirely new or completely abandoned sources were reckoned as unexpected or dropped initial sources.

In addition to the number of sources, the share of sources was calculated. By the share we mean the proportion a source has in a task to be analysed. Naturally, the sum of proportions in a task is one hundred per cent. The proportions of each source were then averaged over tasks in each task complexity category.

Findings

In this section, we present the results on the use of information sources related to task complexity. First, we introduce the main findings concerning each information source; second, we analyse the overall findings concerning expected, dropped initial, materialised and new, unexpected sources. Finally, the relationships between information sources and information types are analysed briefly.

Table 1: The Pearson correlations between task complexity and information source use (both in terms of the average shares of different sources and the number of times used). Statistically significant correlations are in bold.

		Organizational information systems	The Web	Human sources	E-mail	Other	N
by % of all sources	expected	-0.27	0.15	0.16	0.06	-0.04	132
	dropped	0.09	-0.35	0.07	0.13	-0.05	29
	materialised	**-0.29**	**0.39**	-0.04	-0.04	**0.29**	158
	unexpected	-0.03	**0.34**	-0.11	-0.11	-0.03	49
by source count	expected	-0.24	-0.02	0.00	0.03	-0.05	132
	dropped	0.02	-0.19	0.01	0.10	-0.01	29
	materialised	-0.20	0.21	-0.11	-0.12	0.19	158
	unexpected	-0.03	0.24	-0.14	-0.11	-0.03	49

Table 1 presents the correlations between continuous task complexity and information source use. The correlations are quite weak, and only four of them are statistically significant. However, the average proportions of sources are more clearly connected to task complexity than the number of sources; and task complexity is a better indicator of materialised than expected information source use. More detailed findings are presented below.

Organizational information systems. The organizational information systems were the most frequently expected source type in all task complexity categories. The share of information systems reduced with growing task complexity from 62% to under a half. However, the number of times organizational information systems were expected peaked in semi-complex tasks and the difference between semi-complex and complex tasks was statistically significant (Mann-Whitney, p=0.031). All expected use of organizational information systems did not materialise. Organizational information systems had a maximum of 57% share of dropped initial sources in semi-complex tasks. On the other hand, only a fourth of abandoned sources were organizational information systems in simple tasks. In simple tasks, 14% of expected organizational information systems were not used. The share increased a little in semi-complex tasks and to a fourth in complex tasks.

As participants expected, organizational information systems were the most used information source. The share of materialised use of organizational information systems reduced from 59% to a third with increasing task complexity. The difference between simple and complex tasks is statistically significant (Mann-Whitney, p=0.045). In addition, the continuous task complexity correlated with the share of materialised information system use (Pearson's r=-0.293, p=0.026). Discovering new needs for organizational information systems was not as common as the use itself: 36% of new, unexpected sources in simple tasks were organizational information systems and even less in semi-complex and complex tasks.

Organizational information systems were expected to provide mainly known items (39%) and secondly information aggregates (31%). However, of the information acquired using organizational information systems, nearly a half were of known item type, and only 18% information aggregates.

The Web. Expectations of Web use varied from only 6% (semi-complex tasks) to 19% in complex tasks. Up to a third of dropped initial information sources in simple tasks were Web sources, 7% in semi-complex tasks. However, none of the dropped sources were Web sites in complex tasks. Even over a half of expected Web sources were not used in simple tasks. The share decreased to a fourth in semi-complex tasks and as already mentioned, there were no dropped Web sources in complex tasks.

In simple and semi-complex tasks, the use of the Web had only a small share of materialised source use. Compared to this, the share of the Web became prominent in complex tasks (24% of source use). The share of materialised Web use correlated with continuous task complexity (Pearson's r=0.389, p=0.003), and the use was significantly greater in complex than in simple tasks (Mann-Whitney, p=0.045) or in semi-complex tasks (Mann-Whitney, p=0.017). Interestingly, the Web and organizational information systems were equally popular in complex tasks (Wilcoxon, p=0.419), though the use of systems was significantly greater otherwise, i.e., in less complex tasks. Additionally, the Web use expectations differed from materialised use in complex tasks both in terms of the share of all information systems (Wilcoxon, p=0.026) and the absolute frequency of use (Wilcoxon, p=0.014): the Web was used significantly more than expected.

The share of new unexpected Web sources among newcomers was about a fourth in complex tasks and it was significantly greater than in semi-complex tasks (Mann-Whitney, p=0.017). The share of new Web sources also correlated with continuous task complexity (Pearson's r=0.340, p=0.046).

Mainly information aggregates and facts were expected from the Web. The materialised use stressed aggregates more heavily (59%).

Human sources. The share of expected human sources grew with increasing task complexity, being 8% in simple, 11% in semi-complex and 20% in complex tasks. Human sources had quite a large share of dropped initial sources.

Human sources were finally used more than expected, ranging from 18% in simple tasks to 25% in semi-complex tasks, staying at about 20% in complex tasks. The expected number of human sources used was significantly smaller than the materialised use in semi-complex tasks (Wilcoxon, p=0.034) and, in addition, more new human sources were needed than dropped in semi-complex tasks (Wilcoxon, p=0.020). In other words, only one human source out of ten was abandoned whereas almost one new human source was discovered during every other semi-complex task. Indeed, human sources had the largest proportion of new unexpected sources in semi-complex and complex tasks and they shared the largest proportion with information systems in simple tasks.

Human sources were mainly expected when seeking information about larger topics, that is, information aggregates. This also materialised: information aggregates were the main information type sought from human sources (49%), but human sources also provided facts.

E-mail. Expected use of e-mail varied from 14% in simple tasks to 24% in semi-complex tasks. E-mail was seldom abandoned. Only 17% and 13% of dropped initial sources in simple and complex tasks were e-mails and there were no abandoned e-mails at all in semi-complex tasks.

The materialised use of e-mail was astonishingly stable across task complexity categories: the share of e-mail kept around 17%. Only a few new, unexpected needs for e-mail were discovered during task processes and they were independent of task complexity. The share of new e-mail needs varied from 3% in semi-complex tasks to 18% in simple tasks.

Using e-mail was mainly expected when seeking for information aggregates (44%) and known items. The relative strengths of information types changed in materialised use: when e-mail was used, it was most frequently used for finding known items (46%), second most frequently used for finding facts and the least frequently for finding about information aggregates.

Other sources. The use of other sources (mainly of physical or paper type) was infrequent. All expected use of other sources concentrated in the semi-complex tasks (6%) and the materialised use in semi-complex (7%) and complex tasks (6%). The materialised share of other sources correlated with the continuous task complexity variable (Pearson’s r=0.292, p=0.026). Two-thirds of other sources were expected to provide information aggregates and a third of them known items. However, their materialised use concentrates on facts and information aggregates (44% both).

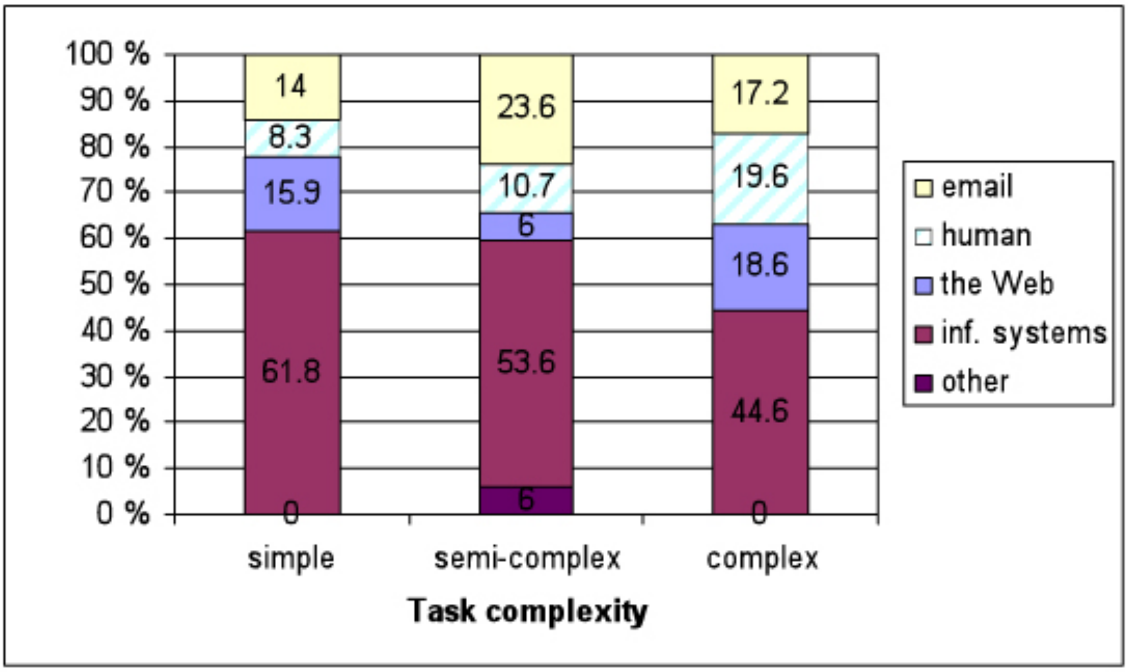

Figure 3: Expected information sources. (N=132)

Expected information sources (see Figure 3). Organizational information systems were clearly the most frequently expected information source across task complexity categories though its share decreased with growing task complexity. Human sources were another source that was affected by task complexity: the more complex the task, the larger the share of expected human sources in an average task.

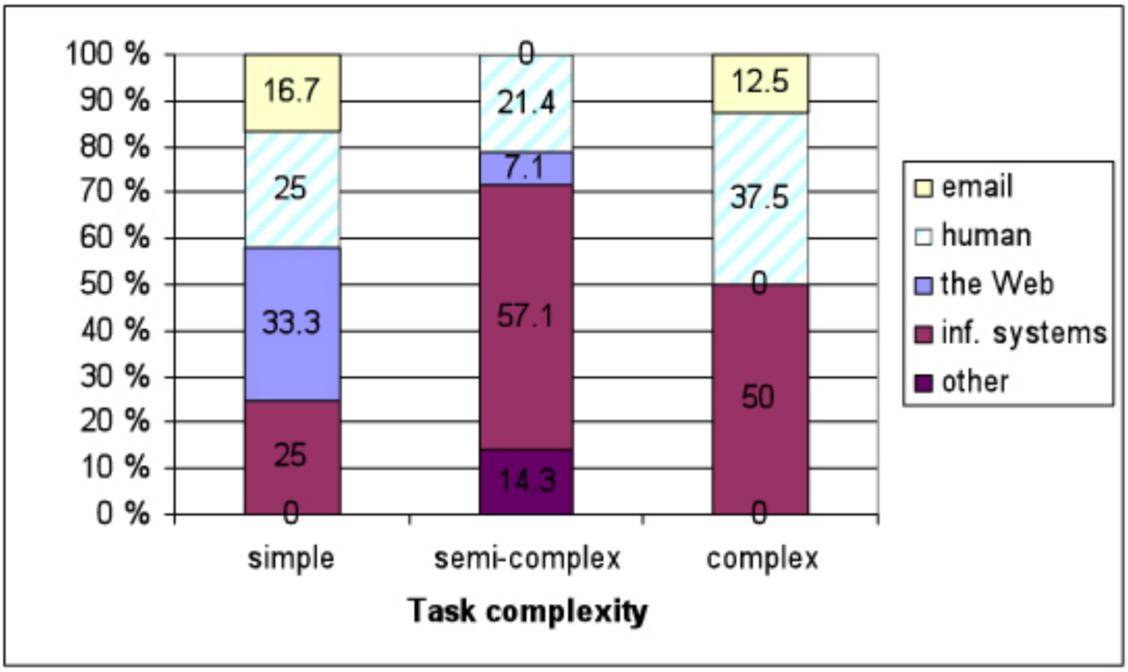

Figure 4: Dropped information sources. (N=29)

Dropped information sources (see Figure 4). The shares of dropped sources were not rectilinearly affected by task complexity, but for Web sources that had the largest share of dropped sources in simple tasks, a small share in semi-complex tasks and finally, in complex tasks, there were no abandoned Web sources. Apart from simple tasks where the largest group of dropped sources were Web sources, organizational information systems were clearly the most frequently abandoned information source.

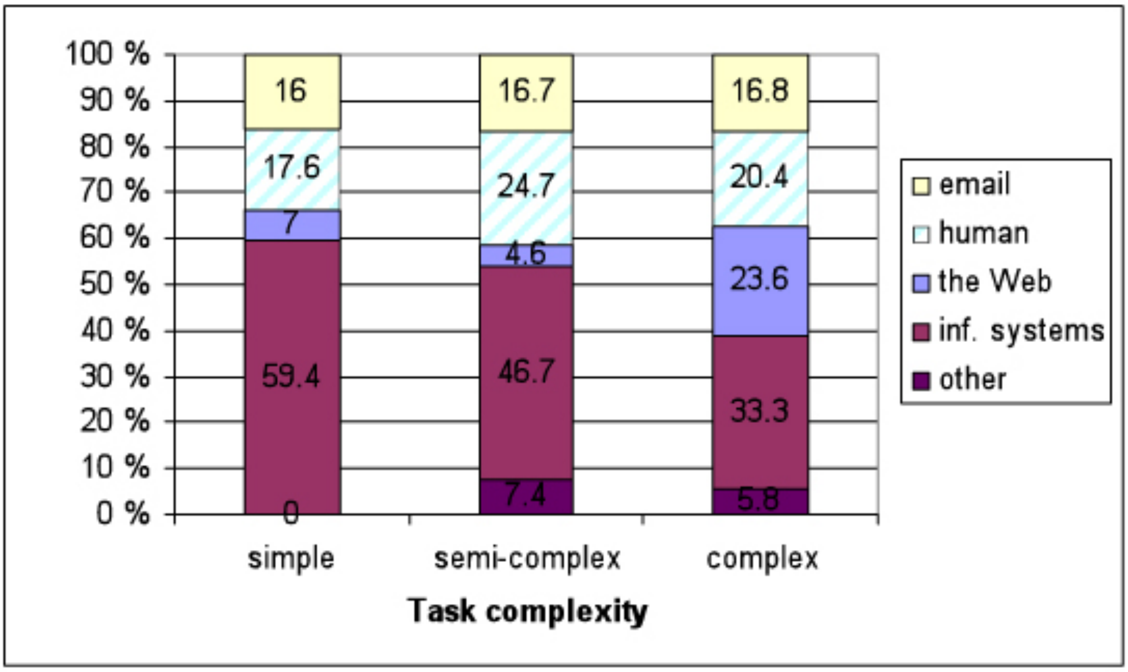

Figure 5: Materialised information sources. (N=158)

Materialised information sources (see Figure 5). Organizational information systems were the most frequently used information source across complexity categories and their share decreased with increasing task complexity as participants expected. However, the total share of materialised organizational information systems was a little smaller than expected. The use of human sources and the Web did not respond to changing task complexity in a linear fashion. In particular, the share of e-mail use was constant despite of task complexity. The sources belonging to the group Other were used little but more often than expected. The data in Figures 3 and 5 are presented in table form in Appendix 4 to enable easier comparison between expected and materialised information sources.

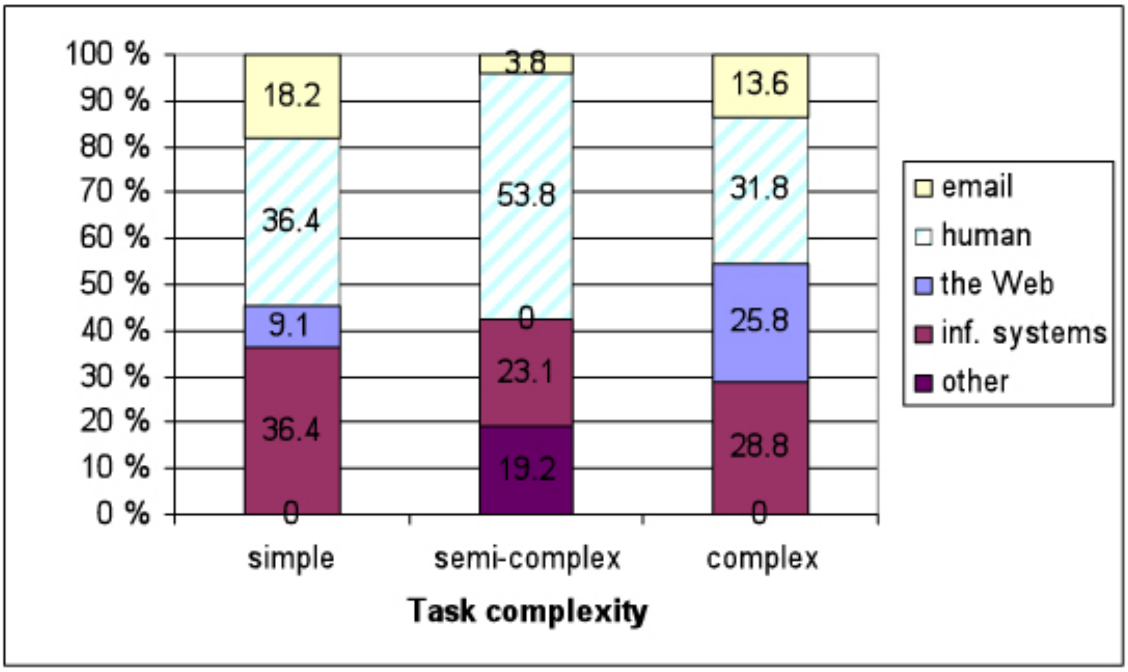

Figure 6: Unexpected information sources. (N=49)

New, unexpected information sources (see Figure 6). The share of new, unexpected Web sources was the only source type where its use correlated with growing continuous task complexity: that is, the more complex task, the more new Web needs were discovered during task process. Overall, human sources had the largest share of new sources regardless of task complexity.

Sources and information types. Information source use was associated with the information types sought for both in terms of expected (Pearson $\chi 2$, p=0.021) and materialised use (Pearson χ^2 , p=0.000).

Table 2: The connections of expected information sources to information types. The most popular information type(s) in each source are in bold.

Source	Information type					
	Fact	Known item	Information aggregate	None	Total	N
E-mail	8.7%	34.8%	**43.5%**	13.0%	100.0%	23
Human	25.0%	10.0%	**45.0%**	20.0%	100.0%	20
The Web	38.1%	4.8%	**42.9%**	14.3%	100.0%	21
Information systems	26.2%	**38.5%**	30.8%	4.6%	100.0%	65
Other source	0.0%	33.3%	**66.7%**	0.0%	100.0%	3
No source mentioned	26.5%	20.6%	**52.9%**	0.0%	100.0%	34
N						166

Information aggregates were the largest group of expected information types in all information sources with the exception of organizational information systems, which were expected to provide most often known items (Table 2).

Table 3: The connections of materialised information sources to information types. The most

popular information type(s) in each source are in bold.

Source	Information type: Fact	Known item	Information aggregate	None	Total	N
E-mail	32.1%	**46.4%**	21.4%	0.0%	100.0%	28
Human	39.4%	3.0%	**48.5%**	9.1%	100.0%	33
The Web	27.3%	13.6%	**59.1%**	0.0%	100.0%	22
Information systems	34.8%	**47.0%**	18.2%	0.0%	100.0%	66
Other source	**44.4%**	11.1%	**44.4%**	0.0%	100.0%	9
No source mentioned	44.8%	0.0%	**55.2%**	0.0%	100.0%	29
N						187

In materialised use (Table 3), human sources and the Web were more focused on information aggregates than expected. A larger share than expected was dedicated to searching for known items in organizational information systems, as well. On the other hand, the focus of using e-mail changed from searching for information aggregates to searching for known items and facts. None of the sources were expected to be used nor materialised for searching mainly for facts.

This inspection also included two special categories, namely the ones where the participants either omitted the information source or information type (see Tables 2 and 3). Discussion of that finding is presented below.

Discussion

In this paper, we emphasised both the importance of studying information source use in various real world tasks and also analysing further the meanings the sources and source categorisations carry. Empirical findings from real life accumulate our knowledge better if we are able to analyse sources beyond the ready-made categories that have been formed to support analysis in single studies. To meet these requirements, we will first discuss our own information source categorisation in the light of easily generalisable source features. After this we will discuss the individual empirical findings and their relationships to earlier studies.

The way of categorising information sources

Previous studies influenced the way we categorised and analysed the data. The time and place of a study cannot be ignored. This holds for both physical surroundings and scholarly context. Our information source classification was data-driven in the sense that the participants had a questionnaire with empty boxes in which to fill in the sources they used, not ready categories to be ticked. This approach has the following benefits: it is applicable to many domains, the data can be classified and reclassified easily, the researcher does not have to discover all possible response variants beforehand and the participants can express themselves freely.

The research goals guided the analysis. This is seen in the way that mediums of information, not the contents, are represented in the categorisation: human sources, e-mail, the Web, organizational information systems and other sources. In summary, any of these source types could be used to search for the same piece of information. Our goal with the instrumental source approach was to describe the task effect on information source use. Eventually, this led to some further findings about connections between information sources and information types.

Our information source categories were quite robust as the data set was small, and each category needed to have enough instances to enable indicative statistical testing. Yet a thorough inspection reveals that even these rough categories encompass more subtle features beyond their labels, as well. The features were demonstrated with examples of earlier studies in the literature review of the present paper. Our source categories differ in how many of these features they encompass. Thus following remarks can be made:

- Humans as sources are communicative. The role of human sources was not specified in the categorisation (expert, colleague, etc.). Human sources in our data set represent the facet communication in Figure 2.
- E-mail is a communication tool that often contains unpublished material, usually as text. In principle, it may contain all kinds of data. E-mail in our data set represents mainly the facets unpublished material, communication, and textual data in Figure 2.
- The Web is an external source, and especially a source with all kinds of material (textual, visual, audio, etc.). The material in the Web is published, that is, publicly available. Thus, the Web in our data set represents facets: published material, externality, and different data types as seen in Figure 2.
- Organizational information systems are the internal, restrictedly shared counterpart of the Web that often have high authority (i.e., they are expected to be used in most tasks or the use is even compulsory in some cases). Licensed Web-based software or services were included in the organizational information systems. Organizational information systems in our data set represent the facets of shared and internal information sources with authority facet.

Human sources and the Web are self-explanatory information source types in the sense that their meaning is close to the corresponding layman's terms. Understanding the role of organizational information systems required more inside information. It was gained both through observational data (Saastamoinen *et al.*, 2012) and the questionnaire responses. Two information source types in particular merit further discussion, namely e-mail and the category *Other sources*. The latter was so heterogeneous that it could not be labelled in the feature list above.

It was quite surprising how clearly the participants saw e-mail as a source type of its own. They did not just name the people they contacted via e-mail but seemed to feel that e-mail as such is a major resource for working and seeking for information. In observational data from the same tasks (see Saastamoinen *et al.*, 2012), e-mail seemed much used, important and diverse within communicational sources but its intrinsic value crystallised only in consistent questionnaire responses.

Why did e-mail come up so clearly, then? We could argue that the participants named the source type they felt was more important, whether a person or a communicational medium. E-mail may have been used as a source label for example when organizing a complicated issue with several people (the medium uppermost). Alternatively, people are listed by name because they are needed for several purposes (the person uppermost). To separate between these two cases our categorisation considers human and e-mail as separate sources. However, most likely the mere use of the e-mail application was not very helpful in performing the task, whereas the content counts, that is, the information carried by the messages that have originally been sent by people to people. On the other hand, as seen in the observation study (Saastamoinen *et al.*, 2012), the e-mail application was also used as a repository for important attachments and messages. This use of e-mail dissipates the communication function, and actually makes e-mail more like a conventional database. In this sense, habitual boundaries between communicational (human) sources and documentary resources can be questioned. In the case of e-mail, these two perspectives are tightly connected.

Our small category for *Other* information sources included all printed books and papers the participants had listed in the questionnaire. *Other sources* were sources that could not be placed elsewhere on good grounds. Though small, the category proved interesting. Because the so-called physical resources were widely used in observational data (see Saastamoinen *et al.*, 2012), it may have implied that this category should have been quite large. This may indicate that though people actually handle plenty of paper documents in their work, they still do not reckon them as sources. Scanning papers may be too habitual to be acknowledged at all. A more probable reason lies in the fact that perhaps little information is found in the scanned papers. This holds for other sources, as well. A source that fails to give the needed information is not a source at all. When studying information seeking behaviour, unsuccessful information seeking is at least as important as the successful one. On the contrary, participants tend to identify a source only when the needed information is found. Of course this does not explain why our participants did not expect that they would use physical sources, either. Perhaps the information should have been found elsewhere but finally they had to turn to paper sources.

Interestingly, observational data revealed that surprisingly many papers were actually printouts even if only files that had been printed during the observation session were counted among printouts (Saastamoinen *et al.*, 2012). A hasty interpretation would be that as a printout contains the same information as an information object in an electronic database, it is an identical and thus an inferior source to the original one. Quite naturally, this is likely to be the participants' interpretation as well because they were seeking for a piece of information, not a source *per se* apart from some known items. However, we do not think that printouts are irrelevant sources. Obviously, they were used for a reason, even if only to gratify a habit. Alternatively, reading on a computer screen was sometimes regarded as uncomfortable, and making notes to an agenda easier with pen and paper than in a word processor. Thus, using printouts may relate to usability problems in electronic environments.

Task complexity and information source use

We found indicative results of the effects of task complexity on information source use. Due to the relatively small data set, we were able to detect and analyse further only clearly rectilinear dependencies. We found that task complexity affects the use of

- organizational information systems
- Web sources, and
- human sources.

The use of these three source types is discussed below. We also discuss the possible reasons why e-mail is a relatively important source despite varying task complexity.

First, the more complex the task, the less use of organizational information systems is expected and the less they are used, as well. A natural explanation is that these systems are originally designed to support straightforward tasks so that human resources can be expended on more complicated tasks. It underlines the principle that the processes that are simple and performed often are automated before long to save monetary resources, and is a finding of the observational data as well (Saastamoinen *et al.*, 2012); the more complex the task, the less there are systems to support the tasks. Byström's (2002) data does not cover electronic information systems because her data were collected before the mid 1990s and electronic systems were not in use then in the administration of the studied city. Byström's categories of official documents and registers are close enough to be compared with organizational information systems. One may state that official documents are found in the (organizational) information systems nowadays. Byström's trend is thus similar to that found in this study, especially the use of official documents dropping with increasing task complexity. Registers are used little in all tasks, but their share of all information sources is smaller in the most complex tasks (decision tasks) than in less complex tasks (normal information processing tasks).

Second, we found that growing task complexity indicates enhanced Web use. The Web and organizational information systems seem to be two sides of the same coin. A similar trend was also seen in observational data (Saastamoinen *et al.*, 2012). The features of Byström's (2002) external literature reflect the features of the modern Web environment. They both are publicly available sources (external literature can be found in libraries, for instance) containing documented information and they cover a larger scale of topics than internal literature or official documents. The information one is seeking for on the Web is not stored in any internal databases because it is seldom needed, for instance. Being a publicly available source also means that the information is not confidential. We can assume that any proprietary documents and/or key information of the organization is only internally available either because of frequent need and usage or because of confidentiality. Overall, the use of literature is minor in Byström's study, but it grows along task complexity. At the same time, the internality of literature drops. In other words, using external literature increases in the same way as the use of the Web in our data. As Byström'sinternal literature is probably provided for frequent use, it seems to relate more strongly to everyday decision making (that is simple tasks) than external literature. The same seems to apply to the differences between our organizational information systems and the Web.

Taken together, it would seem that complex tasks and larger scale ('*outside the box*') information seeking tend to intertwine. If all information needed is found in internal sources, the task may not be regarded as a complex one after all. Thus the performer may evaluate a task as simple afterwards. If performing a task requires plenty of information seeking, especially from external sources instead, the whole task may become more complex. The cause and effect are closely related especially if the task is information-intensive, that is if information seeking forms a major part of task process.

Third, the use of humans as information sources is generally associated with flexibility. They can understand other humans' information needs even if they are vague. Our participants expected that they would use human sources more as tasks became more complex. This trend did not materialise. Although human sources have a bigger share in semi-complex and complex tasks than in simple tasks, the peak was in semi-complex tasks. Interestingly, semi-complex tasks have a high number of unexpected human sources; 53.8% of all unexpected, new sources. The corresponding share is only about a third in simple and complex tasks. In other words, human sources were mostly used in semi-complex tasks and the use was raised by many human sources that are only discovered during task performance. In contrast to the finding of the questionnaires, our observational data showed that communication (including e-mail) increases moderately with task complexity (Saastamoinen *et al*., 2012). The questionnaire data does not support this finding even if we added the use of e-mail to human sources. In other words, our data do not indicate any connections between materialised human source use and task complexity. The interdependence is not clearly curvilinear either, though the peak of use is in semi-complex tasks.

However, it is an obvious trend in Byström's (2002) study that human source use increases along task complexity. Her diary forms were very similar to our questionnaires. Thus this cannot be only a question of choosing a data collection method. One probable explanation of the relationship between human sources and task complexity is rather uninteresting. It may be that people are not aware how much they tend to communicate with other people while performing their tasks. As outside observers we did not assess the significance or success of telephone calls or unofficial meetings; we just calculated them. Another possibility is that these unsuccessful communicational sessions were not reported in the questionnaires. The reader should remember that these are just speculations that are hard to prove without any analysis that only concentrates on communication, which was beyond our research agenda and research questions. Still, the finding that the two data collection methods give different results points to an intriguing area for future research.

Information sources and information types

We discuss here the connections between information sources and information types. The ways task complexity affects information type use are discussed earlier in Saastamoinen *et al*. (2013). The participants were asked to name the source and the information expected (task initiation form) and used (task ending form). The questionnaire data demonstrated that connections between information sources and information types exist. The results are still only indicative. Organizational information systems and e-mail proved to provide mainly known items in materialised use, that is, official documents and attached files. Thus organizational information systems and e-mail best supported well defined information needs that are answered with known item searches. Human sources and the Web were used when seeking for information on broader subjects, that is, information aggregates. Thus they support more vague information needs. An important result is that no source type was mainly used for fact finding. However, all sources were used for fact finding quite equally in the case of materialised use, though facts were not the distinct main information type for any source. The linkage between sources and information types is clearer in case of materialised use.

The participants expected that e-mail would provide mainly information aggregates. However, in terms of materialised use, e-mail proved to provide mainly known items. E-mail is the only source that changes focus in this sense. The participants may have first had a more vague idea that they would need some information that can be acquired via e-mail. Then finally it proved to be a specific message or a file that was either needed as such or that happened to fully satisfy the information need. On the other hand, the participants did not expect to use e-mail almost at all when searching for facts, either. In the materialised use, however, a third of e-mail use focuses on facts. The explanation could be similar to the one stated above. E-mail is expected to be useful when information needs are relatively general, but what it actually offers is more restricted information.

Byström (1999) found some indicative information about typical sources of information types. She found that people are used as sources of all kinds of information types whereas official documents and registers are used for obtaining task information and literature for accessing domain information. As already stated above, we can conclude that human sources are more flexible than documentary resources. Our facts and information aggregates are roughly comparable to Byström's task and domain information. In our data, human sources are expected to offer mainly information aggregates, and some factual information, too. Known items were not expected, reflecting the way the use of human sources materialises. In this respect, our data do not support the assumption that people provide evenly all information types. It seems quite natural that people do not hand known items to each other; known items are sent via e-mail or they can be found in organizational information systems. At least in the organization studied, it seemed that known items - though certainly often produced by humans - were mostly not person-sensitive, such as official documents. In this sense, e-mail was seen as a source rather than the person who passed an agreement, for instance. In contrast, person-sensitive known items could be personal e-mailed messages where the sender rather than the medium was marked as the source.

As we noticed in an earlier section, the use of literature in Byström's study (1999) can be compared to the use of the Web in our study. They both are able to provide information on larger subjects in addition to a single fact or information needed in a single task. Byström found that registers and official documents provide narrow information which holds true for our (materialised) use of information systems, too. Though information aggregates are expected to be found in organizational information systems, those expectations seldom materialise.

However, all these similarities with Byström's findings do not reckon with two dissimilar information types that the two studies have. They are task-solving information in Byström's (1999) data and known items in the present paper. Task-solving information was not recognisable in our questionnaire data. It is also a little more challenging to identify than the other information types. In other words, it relates closely to the actual use of information. Other information types discussed here rather exemplify the richness of information or the potential use of it (narrowly or widely exploitable information).

We conclude our discussion with the following propositions: No single source was heavily relied upon when searching for facts (that is narrowly exploitable information). Organizational information systems were used when searching for known items. Furthermore, people were little used for known item needs – thus people were not perfectly flexible regarding information types. On the other hand, people were the source category most often stated as such, without an explicitly named information type, which may indicate the importance of a human source as a whole. The participants expected that the use of information systems be diverse but this did not quite materialize. E-mail proved to be the most flexible source in the end, which may be explained by its versatility as both a documentary and a human resource.

Data asymmetry

Sometimes either the source or the information was not present in the answers provided by the study participants. For the sake of data symmetry, these cases are included in the present analysis of both the sources and the information types. Cases without a source were omitted from the analyses of pure information source use. Obviously, when some expected sources were missing from the questionnaire replies, they may have been unclear to the participants. That is they did not know beforehand where to seek for the information. Thus these unknown sources inherently differ from sources belonging to the group *Other*, in which category the source was known and written down, but in the analysis phase it could not be placed in any of the existing categories. This happened to printed books, for example. The categories for other sources and unknown sources are naturally the same in the side of materialised sources. Nonetheless, the interpretation of missing materialised sources (where only an information type is present) is more troublesome. Why did the participants not always report the source though clearly asked and certainly known? Some of these twenty-nine cases were certainly accidents and misunderstandings. For instance, sometimes an information type (as we define them in the present paper) was put both in the box for information source and in the box for the information itself (differently framed, of course) rather than naming a medium as a source. Yet there was not a single case where the box for materialised source would have been left blank intentionally. Bearing in mind that the study was descriptive and the analysis was data-driven, the participants' replies were not restricted to our understanding of information types and sources. These kinds of *mistakes*, or rather discrepancies, tell us something about a) the nature of questionnaires as a data collection method; and b) the way participants understand their sources. The latter point is why we wanted to analyse the whole data rather than reduce it substantially by omitting the cases without correct source information in the right box. Certainly, the instructions given to the participants could have been more precise, as well. Using questionnaires leaves the interpretation of concepts to participants.

In conclusion, we argue that a task performer holds back (either consciously or unconsciously) the part that is less important for the information seeking process. This resembles the fact that participants often failed to "remember" all paper sources used (see discussion above). In the task initiation forms, either information type or source was missing, whereas in the task ending forms only a few instances were without an information type. The source was still omitted quite often. Perhaps a person is named as a source without information type because she is needed for many purposes in the same task, even as intellectual support. Thus the person as a source was likely to be more important than any piece of information she could give separately. If an information aggregate was needed, and no information source was reported, perhaps pieces of that information aggregate were found in several places. Or, the source is simply secondary because the need for an information aggregate is overpowering. This results in naming an information type as the source as well.

Conclusions

In this study, we analysed the effects of task complexity on expected and materialised information source use and the connections between information sources and information types. Collecting data on information seeking activities in real work tasks is important relative to both accumulating knowledge and developing better information tools. We should understand information seeking as a process that includes using several sources. Furthermore, these processes are part of tasks that inflict information seeking.

We found that organizational information systems were by far the information source type that was expected to be used the most. This is understandable as the organization studied was the administration of a city; the nature of the organization demands most of the tasks to be routine and at least partly predefined and thus also automated. Thus organizational information systems supported many tasks well. However, organizational information systems were more often abandoned during task performance than any other sources.

The materialised use of organizational information systems followed participants' expectations in the sense that it was the most popular information source type. Human sources were the second most popular source but they were used one half less, so information systems were quite overwhelming in popularity. However, people were the source category that included the most new, unexpected sources, and here organizational information systems came in second.

Our results indicate that task complexity affects the use of some sources more than others. We found that higher task complexity is connected to increasing expected use of human sources and materialised use of the Web, whereas organizational information systems are expected to be used and finally used less when tasks become more complex. Concurrently, the Web's share of all new, unexpected sources increases and its share of dropped sources decreases with growing task complexity. Also the dropped Web sources' share of expected Web sources decreases with growing task complexity whereas the dropped organizational systems' share of expected organizational information systems increases with growing task complexity. Further, the materialised use of e-mail stays surprisingly constant throughout task complexity categories.

None of the sources were expected to be used nor used mainly for fact finding. The study participants expected that they would mainly be looking for known items when using organizational information systems. Within all other source types, information aggregates were the information type they expected to be needed most frequently. The situation changes a little in materialised use, as e-mail is actually used when searching for known items, not information aggregates.

Our results add to the still shallow knowledge on task based information seeking activities in real life environments. A similar study was conducted in the 1990s (Byström, 2002) and thus also historical contrasting is possible. Further, we collected different kinds of data through observation (Saastamoinen *et al.*, 2012) and questionnaires (reported here and in Saastamoinen *et al.* (2013). This enables fruitful, empirical comparison between data collection methods.

However, a single study, bound to its temporal and spatial limitations, cannot reveal all aspects of the studied phenomena. The main limitation in our study was the relatively small data set and the challenges it posed to the analysis and interpretation. Our indicative findings need to be tested again, preferably in organizations that differ from local government, for example a business environment. It is important to examine whether tasks of similar complexity induce similar information seeking behaviour across different professional contexts.

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Appendices

Appendix 1: Orientation form (translation, original in Finnish)

Contact information

Name:
E-mail address:
Telephone number:

Background information

Your official job title:
Are you in a supervisory position?: Yes/No
The highest educational degree you have completed:
The other most important studies related to your work and their extent or duration (e.g. "Skills needed in work" -course, 1 year and 2 months).:
How long have you been in your present work in the present position or equivalent (e.g. 1 year and 2 months)?:
Your responsibilities:

Work tasks

How varied do you find your tasks?: Very similar/Similar/Varied/Very varied
Think what kind of task types you can recognise in your present job. Please describe some of them briefly.:

Sources

Which information systems and information sources do you normally use in each work task you mentioned above?:
What information do you search for in each source you mentioned above?
Does some specific information system or information source facilitate your work especially? How?:
Do you find it difficult using a specific information system or an information source? Which one? What kind of problems have you encountered?:

Appendix 2: Task initiation form (translation, original in Finnish)

Please answer these questions based on your task at hand before you commence performing it.

Background information

Your name:
Describe the task:
What is your role in performing the task?:
How often do you perform similar tasks?: Daily/Weekly/Monthly/Less frequently

The beginning of the task

Estimate how complete the task was when you got it (%):
How well does your expertise match the know-how needed in the task? (0=”All in this task is totally new to me!”, 100=”All in this task is totally familiar to me!”):
How complex does the task appear to you? (0=really simple, 100=really complex):

Performing the task

Describe factors independent of you that may affect performing the task:
Estimate how well you know the task stages beforehand (0=the task is still utterly strange; 100=I know exactly the stages needed):
Estimate, how well you know, what information you need in order to perform the task. (0=the information needed yet totally unknown; 100=I know exactly the information needed):
What information sources or systems do you think you are going to use when performing the task?:
What information do you seek in these sources?

Outcome

What is your ambition level concerning the task?:

- I want to get rid of it as soon as possible.
- I would like it to be done well .
- I’m satisfied only with a really good result.
- None of the above mentioned (describe in the next field).

Your ambition level in your own words:
How precisely do you know the outcome of the task? (0=I do not know the outcome at all, 100=I know exactly what the outcome should be like):
Describe the task outcome as accurately as possible:

Appendix 3: Task finishing form (translation, original in Finnish)

Please fill in at the end of work task performance.

Background information

Your name:
Work task completed:
Date of beginning the task:
At which stage of the task did the shadowing take place?: At the beginning / In the middle / At the end
How large a share of the task performance did the shadowing encompass (%)?:

Satisfaction

How satisfied are you with the task result?: Really satisfied / Satisfied / Neutral / Unsatisfied / Really unsatisfied
Why are you / are you not satisfied?:

Information seeking

Which sources did you use? (In two columns the answer should be on a scale of one to five; 1=totally disagree, 5=totally agree.):

Source	Information sought	Info. was found (1-5)	Info. was adequate (1-5)

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Search task features in work tasks of varying types and complexity

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Abstract
Information searching in practice seldom is an end in itself. In work, work task (WT) performance forms the context, which information searching should serve. Therefore information retrieval (IR) systems development/evaluation should take the WT context into account. The present paper analyzes how WT features: task complexity and task types, affect information searching in authentic work: the types of information needs, search processes and search media. We collected data on 22 information professionals in authentic work situations in three organization types: city administration, universities and companies. The data comprise 286 WTs and 420 search tasks (STs). The data include transaction logs, video recordings, daily questionnaires, interviews and observation. The data were analyzed quantitatively. Even if the participants used a range of search media, most STs were simple throughout the data, and up to 42 % of WTs did not include searching. WT's effects on STs are not straightforward: different WT types react differently to WT complexity. Due to the simplicity of authentic searching, the WT/ST types in interactive IR experiments should be reconsidered.

Introduction
Much of modern work is information-intensive and supported by diverse information systems. Information supply and searching are key activities in information-intensive work. Work tasks (WTs) are the building blocks of work. A job description includes abstract WTs that manifest as WT actions in daily work (Byström & Hansen, 2005). In working life, WT performance forms the context, which information supply and searching should serve. In order to design information search systems to properly serve WT requirements, it is necessary to study how the WTs as actions are connected to searching. Therefore information (retrieval) systems development and evaluation should not take place in isolation but take the work context into account and find out for what purposes and how the systems are used. Failing to do this may result in developing suboptimal systems for expected but biased search needs. In the present paper we aim to find out, how searching is carried out in work contexts and what affects it.

Several researchers highlight the importance of task-based information searching (TBIS) as a research area (Järvelin et al., 2015; Kelly, Arguello, & Capra, 2013; Vakkari, 2003). However, naturalistic field studies of TBIS are rare. Other types of empirical approaches to TBIS seem more common, including log analyses (e.g., Kotov, Bennett, White, Dumais, & Teevan, 2011), simulated WTs (e.g., Borlund, 2003), self-report methods (e.g., Li, 2009), and semi-naturalistic studies (e.g., Pharo, 2004).

The present study belongs to the naturalistic field studies, where information searching is studied in the context of authentic WTs, at the work place, collecting multiple types of data in real-time. There are some predecessors to the present study, e.g., Hansen's (2011) study on TBIS in the patent domain; Saastamoinen, Kumpulainen, and Järvelin's (2012) study in the public administration domain; and Kumpulainen's (2014) study in Molecular Medicine. Also Kellar, Watters, and Shepherd (2006) and Kelly (2006) used naturalistic methods but their work was more concerned with leisure time activities than WTs.

We consider major search task (ST) features that have received little attention in past research, under the influence of WTs. First, information searching is typically studied in a limited context, where the searcher has only *one given search tool* to use. In reality, there are several options the searcher can choose from. Second, in experiments, the searcher cannot choose to use *more than one search tool* though this is often possible in real-life. Third, *information needs* are typically studied narrowly: Either the need is almost directly given to searchers (in the case of simulated WTs), or the searchers are asked to describe their needs (in self-report studies), or researchers attempt to reconstruct information needs based on a sequence of queries and clicks (in log analyses). These approaches are unable to show the existence and/or prevalence of these information needs in reality. Fourth, modeling *search processes* is often neglected in favor of result list ranking and relevance of individual documents. Fifth, *participants* are often students, or employees of a single organization. Thus the generalizability of the findings concerning their practices may be limited.

To overcome these limitations, we propose analyzing information need formation and search tool use in naturalistic STs in authentic and heterogeneous WT context. This will shed light on whether current TBIS research addresses issues prevalent in authentic STs/WTs. Furthermore, real ST processes should be analyzed if we want to understand and support them better. We think that it is necessary in information searching experiments to study heterogeneous search environments and WTs; or, the WTs have to be problem-centered rather than search-centered.

The present paper studies perceived WTs and their subtasks, STs, that were inferred from the data. Each ST has one underlying information need, a driving force to begin searching. The independent variables are *WT type,* a cross-domain data-driven categorization, and (*perceived) WT complexity,* a traditional and significant variable in earlier TBIS studies (e.g., Byström & Järvelin, 1995). The dependent variables are the ST features: information need and ST process, the main search medium, and the number of unique search media. The present study is unique in its *combination* of the amount of authentic data collected and its diversity, the quantitative approach and the dependent variables.

Altogether 22 participants in three types of organizations were followed performing 286 WTs including 420 STs. The data include transaction logs, questionnaire responses, observation, screen video recordings and interviews. These features allow the study of issues often neglected in earlier studies: what search media are used if people can freely choose among those available and whether there are several of them; what are the participants' authentic information needs and how the participants act to fulfill them.

The rich data set also includes other analyzable search features, e.g., concerning the queries. For reasons of readability and length, findings concerning these features are discussed in another paper (Saastamoinen & Järvelin, 2016).

Related research

Concepts

Work tasks (WTs) are formed of the actions performed in order to achieve a goal, the task outcome (Vakkari, 2003). *Search tasks* (STs) are subtasks of WTs. Various WT and ST features are discussed in information studies literature (Li & Belkin, 2008).

WTs are often classified in TBIS studies based on their *complexity* and *difficulty*. These two concepts are neither identical nor independent of each other. (Liu, Kim, & Creel 2015; Wildemuth, Freund, & Toms, 2014). Another classification divides complexity into *objective* vs. *subjective* measures (Liu & Li, 2012). Liu and Li (2012) argue that these terms are often confused while Gwizdka and Spence (2006) and Maynard and Hakel (1997) found that they nevertheless correlate. In the present study, we apply subjective WT complexity. Without in-depth substance knowledge of the study participants' tasks, assessing objective complexity would have been prone to mistakes if not impossible.

Information needs induce STs. We apply an information need categorization similar to Broder's (2002) but use it to describe the intent behind the whole ST instead of a single query. Broder's (2002) taxonomy includes navigational, informational and transactional searches. We classify information needs into instrumental (the intention is to perform an action or navigation) and content-driven (new information needed); and in the latter case, into factual, topical, or known item needs (cf. Ingwersen, 1986; Ingwersen & Järvelin, 2005; Toms, 2011).

Kumpulainen's (2014) search trails inspired our classification of *ST performance processes*. She analyzed five types of trails. Our classification is similar except for one type, 'chain', which seemed specific to the field she studied, molecular medicine. Our classes were identified in the data and are: single, list, stable and developing process. These are explained in detail in the Analysis section.

Approaches to TBIS

There are several empirical approaches to TBIS. Next, they are briefly discussed.

Log analyses exploiting search engine log data are unbeatable in the quantity of data. However, logs do not offer factual knowledge about the underlying WTs. One may try to reconstruct the STs based on the log (e.g., Kotov et al., 2011) but without further information these are mere approximations. Furthermore, typical log studies include only queries to a single system, while different (types of) systems may be used in authentic WTs. However, if a log study is conducted in a naturalistic environment with background information, it may provide a great contribution for TBIS. For example, Kellar et al. (2006) collected logs of students' Web usage in their own computers and found four main ST types that affected search behavior.

Simulated WTs (Borlund, 2003) are pre-constructed STs that have a short background story providing motivation and a frame for searching. They work as simulations of real situations when they are carefully designed, so that the participants can identify with the task at hand. However, the veracity of simulated WTs is left to the imagination of the researcher.

Self-report methods employ diaries (Du, 2014), surveys (Nicholas, Williams, Rowlands, & Jamali, 2010) or interviews (Li, 2009) in data collection. Self-report methods are quite straightforward to apply but their results are not always reliable because participants may report their actions inaccurately.

In semi-naturalistic studies, information needs and tasks may be authentic but information searching occurs in a controlled environment (e.g., Pharo & Järvelin, 2004; Vakkari, Pennanen, & Serola, 2003). This supports control of data collection but significantly limits the participants' choices in TBIS.

Naturalistic field studies are rare in information searching research, perhaps because they require plenty of resources. In only a few studies (e.g. Hansen, 2011; Kumpulainen, 2014; Saastamoinen et al., 2012) researchers arrived at the work places of participants to follow their authentic work rather than bringing the participants into a controlled environment to perform assigned tasks. However, often the number of participants in the studies is low and little if any quantitative results are gained. The main findings of naturalistic studies of TBIS include:
- When WTs become more complex, more information system integration is needed, and search situations become more complex because of lack of automated integration and the need to generate manual workarounds (Kumpulainen & Järvelin, 2010; Kumpulainen, 2014).
- Information needs often develop during an ST (Hansen, 2011). This confirms earlier views by Bates (1989) and Borlund (2003).
- Along increasing WT complexity, the use of network sources (including the Web) increases, whereas the use of organizational information systems decreases (Saastamoinen et al., 2012).

Past studies indicate that tasks affect the use of information systems and need for their integration. Multiple information systems are used in WTs. These are findings which are hardly taken into account in traditional information searching studies but which are clearly visible in the field. At best, these approaches complement each other and any single study type is insufficient alone.

Research design

Research questions

Earlier studies have focused on either maximizing quantitative data, but largely ignored context, or on maximizing qualitative data by analyzing the actions of a few participants in great detail, but excluded the possibilities for generalization. Moreover, asking participants what they did does not yield quite as reliable data as one may collect by observing and logging their actions. We aim at a large, quantitative analysis of TBIS with focus on WT factors affecting search. This helps design better information systems and better experimental studies in the future.

On the basis described above, we study four STs features: the main search medium, the number of unique search media, the types of information needs and ST processes in each of the following research questions:

1 How does subjective WT complexity affect STs?
2 How do WT types affect STs?
3 What is the combined effect of WT type and complexity on STs?

Data collection

The data collection took place in authentic working environments. All WTs are authentic. Twenty-two knowledge workers participated in the study. They worked in six organizations; a city administration (10 participants), two commercial companies (7) and three universities (5). The participants were recruited through personal connections to these organizations. The participants got two movie tickets per person (for those who had participated for several days). Figure 1 presents the data collection protocol.

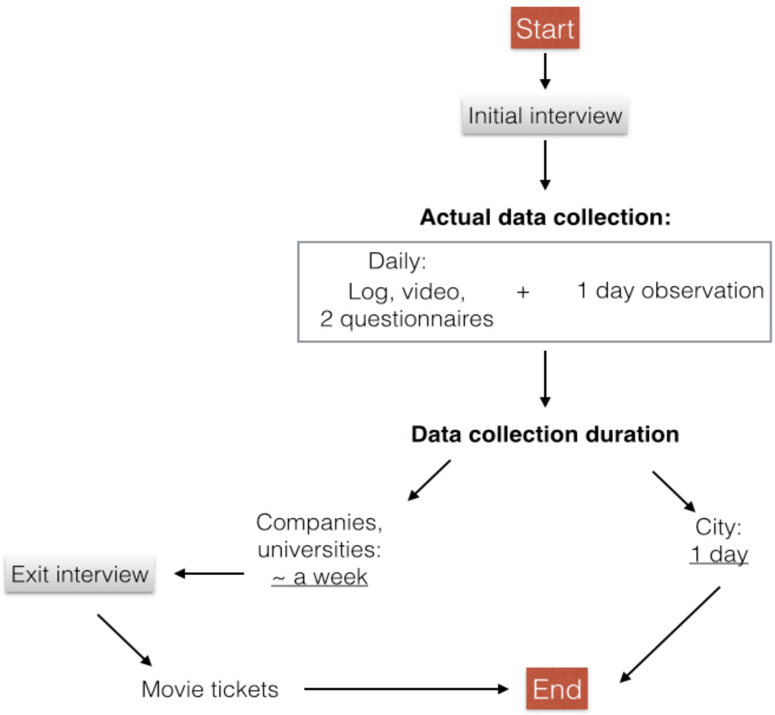

FIGURE 1. The data collection protocol.

The data were collected using multiple methods. The first step was a free-form recorded opening interview with each participant, aiming to give the researchers an understanding of the participants' work and help create a confidential relationship between the parties. The participants were asked to tell about their WTs, information sources, and search practices in particular. After the interview, we agreed on the days of actual data collection. The settings of the data collection software were also checked and instructions given on their use. The study software was installed by the technical support of each organization.

The duration of data collection varied by participant and organization from one to 11 days. On each day, participants filled in an electronic questionnaire (Appendices 1-2) when beginning to work and just before leaving from work. In the morning, they filled in the expected WTs of the day, their complexity, and the information systems and other sources they expected to use. In the afternoon, they listed the WTs performed, their complexity and the information sources used.

Information interaction during the working days was recorded with a logging software (Figure 2) and a screen capture software. The software did not cause serious problems in computer performance. The participants were given instructions about the data collection procedure in writing and orally with continuous support offered by email/phone. To preserve confidentiality, the participants were able to stop automatic logging, delete rows from the log, or put 'private' tags on the log for the researcher to delete confidential data. Some participants used these options. After removal of the confidential sections, the logs consisted of 40 200 rows.

Name	Start	End	Duration	Process
Microsoft Excel - Selection 1-5 2014 READY.xls [Compatibility mod	29.01.14 14:23	29.01.14 14:24	00:00:06	Microsoft Office 2010
GLINK	29.01.14 14:24	29.01.14 14:24	00:00:05	gl
Microsoft Excel - Selection 1-5 2014 READY.xls [Compatibility mod	29.01.14 14:24	29.01.14 14:24	00:00:06	Microsoft Office 2010
GLINK	29.01.14 14:24	29.01.14 14:27	00:03:16	gl
No topic – Message (HTML)	29.01.14 14:27	29.01.14 14:27	00:00:18	Microsoft Outlook

FIGURE 2. An example of the log exported from the logging software. All original Finnish texts are translated in the

figure for clarity reasons. Any confidential information has been removed. 'Glink' refers to an emulator whose name appears when the participant is using an organizational information system.

One data collection day involved a free-form direct observation, lasting for the whole working day. The participant was advised to work normally. The researcher sat next to her, observing her work, using voice-recording and pen-and-paper to record the participant's actions. The researcher asked questions for clarification, such as, 'Which WT are you doing now?', and 'What are you searching for?'. Notes were taken when necessary, especially on non-computer-based actions. Observation supported greatly understanding the events in the log and, therefore, the reliability of the analysis. A multi-day observation would certainly have provided richer data but this would have severely complicated the recruitment process.

After the data collection finished, the researcher met the participant to fetch the log data. The participant asked the technical support of her organization to uninstall the software used.

An exit interview was held a few weeks after the data collection phase with the 12 participants, whose data collection lasted more than one day. Before the interview, the researcher performed a preliminary data analysis. This consisted of identifying WTs and interesting or unclear queries, which were then discussed in the interview. Typical questions were whether a WT mentioned in the morning questionnaire but missing in the afternoon was deliberately omitted or just overlooked; whether a row in the log was part of some WT; where the boundaries between WTs were; and what was the reason for a query. The participants were shown parts of the log or the screen video when necessary. The interview was recorded.

Table 1 shows the basic distributions of the data between organization types. We were allowed to collect data only one day per participant in the municipal administration. However, this was not considered as an issue since we do not analyze differences between organizations. Rather, each participant represents her own WTs.

TABLE 1. Data overview. Minimum and maximum by participant in parentheses (min-max).

	Companies	**City**	**Universities**
Participants	7	10	5
Sample job roles	Design manager, marketing professional	Communications manager, communications officer	Teacher, researcher
Data collection days	37 (5-6)	10 (1-1)	30 (4-11)
WTs	138 (14-28)	47 (3-6)	101 (14-36)
STs	192 (13-48)	55 (1-11)	173 (6-97)

Analysis

For the analysis, we had electronic questionnaire responses, logs, screen capture, observation notes and interview data to answer our research questions. The preliminary analysis conducted before the exit interviews provided a useful basis for the analysis. Below we describe initial WT identification, WT type and complexity categorizations, ST identification and feature categorization, and statistics. Table 2 provides an overview on how the data were used.

TABLE 2. Data types.

Data type	**Function**
Initial interview	- understanding the work of the participant - telling the participant about the study - agreeing on details about data collection
Morning questionnaire	- two out of three WT complexity estimates - task descriptions as a basis for WT type classification - information about which tasks are likely to be performed - potential information source use; helps to spot the WTs in the logs
Transaction log	- concrete steps of work, divided into WTs and STs by the researcher - the number of unique search media in STs - basis for the classification of ST features
Screen video	- concrete steps of work in visual form - understanding the textual log

	- spotting WTs and STs - support for the selection of suitable search feature categories for each ST
Observation	- support for interpreting the log - reliably spotted WTs - understanding the ways participants work
Afternoon questionnaire	- one out of three WT complexity estimates - task description as a basis for WT type classification - information about which tasks were performed - information source use and estimated time of performance helping to spot WTs in the logs
Exit interview	- knowledge about WT boundaries, STs and unclear parts in the log

We started by identifying the WTs in the data. The morning and afternoon questionnaires of each day were compared to each other in order to link the WTs that were mentioned in both, and find which ones were mentioned only in one of them. The next step was to find these tasks in the log and screen video. The clues were collected from all data types, and the exit interview helped a lot. Some tasks could not be found because they were not actually performed, others because they were performed but did not include any use of a computer (e.g., some meetings) and were thus excluded from the analysis. Otherwise, all the WTs mentioned in the questionnaire(s) and recognizable in the log or in the video were included in the analysis.

We did not need to give the participants detailed instructions about how to describe or define their WTs since they were capable of doing that in the first interview. Indeed, the questionnaire responses show that people across different fields and work roles were able to similarly recognize the WTs that they believed forming their work day, and name them recognizably and at the same level of abstraction.

WT complexity and type

Our WT complexity measure is formed of three figures, each on a scale from 0 to 100 percent, as estimated by the participants: a) pre-task complexity; b) post-task complexity; c) amount of prior knowledge of task process. The complexity is the average of a, b, and the complement of c calculated using formula (a+b+(100-c))/3. As an example, if a participant estimates a WT to have 20% complexity in the morning (a), 10% in the afternoon (b), and she estimates her prior knowledge of task process to be 90% (c), the WT complexity is calculated as (20+10+(100-90))/3 = 13.33%. In case of any missing estimates, the above formula was used as an average of the remaining components. Similar measures have been successfully used earlier (e.g., Byström & Järvelin, 1995; Kumpulainen, 2014; Saastamoinen et al., 2012). Using the average of three estimates better represents the underlying WT complexity. For example post-task complexity is prone to the effects of any problems occurring at the end of the WT.

In addition to the continuous WT complexity variable, we categorized WT complexity to allow more analysis types. We categorized WTs into four (as close as possible) equally large categories. The categories are I (tasks from 0% complexity to 21.7%), II (21.8-38.3%), III (38.4-50%) and IV (50.1-100%). This categorization allows us to study the effects of relative complexity in the data.

After data collection, we saw that also another dimension of WTs would help elaborate the effects of WT complexity. However, earlier studies did not provide us with a ready suitable categorization. By carefully reading the task descriptions, we created a tailor-made categorization. The classification reliably separates task types from each other, potentially relates to information searching and use, is not inherently related to task complexity, suites all organizations studied, and divides the data into categories of roughly the same size in order to enable comparisons between the task type groups. The process of forming these two categorizations, WT type and complexity, were independent of each other: neither categorization affected the other one. The types are as follows.

In *communication tasks*, the communication scope stands out in the description: it includes informing, being informed or both, e.g., ‘Handling emails’. This category is similar to collaboration or group tasks studied by Foster (2006).

Support tasks are often administrative but they can be other (almost) mechanical WTs as well. WTs that include several mixed smaller tasks are also considered as support tasks. Support tasks may coincide with routine tasks, a task type presented by for example, Li and Belkin (2008) but our support tasks do not need to be frequent.

Editing and *intellectual tasks* include a creative aspect. The difference is that in intellectual WTs, participants create something from the beginning, whereas in editing WTs, the groundwork is already done, or the objective is to make only final edits. Intellectual tasks typically require cogitation as in the case of writing a report or making a significant decision. Editing tasks include finishing a text, commenting on texts or giving marks to students. Similar task types to our editing and intellectual tasks are Algon's (1997) 'report generation', Hackman's (1968) 'intellective tasks', and Li and Belkin's (2008) 'intellectual tasks'. Our support, editing and intellectual tasks form a continuum similar to task complexity, later called the *sup-edit-int continuum.*

Intra- and inter-classifier reliability tests concerning WT type classification were performed. The average agreement of two inter-classifier tests was 78% (Cohen's Kappa .69). Intra-classifier reliability was 88% (Cohen's Kappa .83).

ST features

We defined STs as subtasks fulfilling two necessary conditions: an ST has a somewhat unified 'information need', i.e. an underlying reason to search (a goal), and contains at least one query. STs cannot overlap. Mere browsing a directory (without a query) does not comprise an ST. The identification of STs within WTs was far from trivial since STs are self-initiated and self-constructed by the searchers. The STs do not manifest themselves through explicit labels like in the logs of interactive information retrieval (IIR) experiments.

A query is identifiable either in the log or in the screen capture video or both. A query contains characters written by the participant and a command to search. Queries can also be issued by selecting pre-defined values in a drop-down menu or by checking menu boxes and giving a search command.

Each ST includes querying in some *search media*. Search medium as concept is similar to the information source discussed in several papers. The difference is that search media are sources used by querying, not for example by browsing. We identified four categories of search media: communication channels (e.g. email), organizational databases, the Web, and personal computer (PC) (e.g. directory search). We also identified unique search media within STs. For example, a search engine and a Web dictionary are two unique media while belonging to the same main search media category, the Web. The main search medium is the one that received the greatest number of queries within an ST.

Our approach to *information needs* here is quite practical: they represent the goal of the ST rather than the mental stage of the searcher. It is possible that the mental stage of the searcher develops during the ST, i.e. the intent behind each query may be a little different (see also ST performance processes below). However, our information need categorization is meant to describe the intent behind the whole ST, not individual queries. We identified the four information need categories: factual, such as a name; a known item when looking for a unit of information, such as a file, known or expected to exist; topical when the searcher wants to know more than a fact; or instrumental, when the searcher wants to accomplish something, such as navigation.

Each ST is realized as a process, the *ST performance process*. STs with one query belong to the category *single* process. A *list* process means a sequence of independent queries, where each query has its own but related information need motivating it, such as checking whether the telephone numbers in a file are correct. In a *stable* process, the intent behind the search is a coherent whole. The results collected during the process do not essentially affect the queries. The list and stable processes differ in that the connection between queries in a list is more of a technical matter while in stable processes the connection lies more in the contents. In a stable process, the searcher may have a topic in mind that she is able to find in smaller pieces for aggregation. In a *developing* process, queries build on each other and the information in the previous results.

For further analysis, we organized information needs from the most simple to the most complex, that is, instrumental, factual, known item, and topical. ST performance processes were similarly ordered, that is single, list, stable and developing. These are called information need complexity and performance process complexity classifications.

All ST features presented above are close to the ones common in the literature. We have adapted them slightly to our data. This was necessary in order to describe information searching in authentic WTs. We sought to keep the modifications minor to serve the comparability of our findings with prior studies.

Statistical analysis

Simple statistical methods were used in the analysis. Though our data set was a convenience sample, the tasks studied can be considered as representing at least some features common to tasks beyond the data. After data collection, WTs and ST features were classified making the data well-structured. The rather large size of the well-structured data allows the use of statistics to support the interpretation of the findings. We use Pearson correlation ('r') for continuous variables, Spearman correlation ('ϱ') if a variable is ordinal, and we perform chi-squared tests ('χ^2') for cross tabulations. Statistical significance ('p') is tested for all analyses; we set the limit for significance at p=.05.

Because STs or WTs were not controlled in any way, the data are authentic. This provides 'noisy' data, i.e., direct, measurable connections between work and ST features may be weak due to intervening uncontrolled factors. However, the connections found, or their absence, are important because they exist in authentic environments. The connections can be studied further in controlled experiments, which is beyond the scope of the present paper. For reasons of clarity and brevity, only the results of the most interesting statistical analyses are reported alongside the findings.

Results

We first discuss the overall findings, then the effects of WT complexity on ST features followed by a similar section, on results concerning WT types' effects on STs. Finally, the combined effects of WT types and complexity on searching are analyzed.

Data profile

The data consist of 286 WTs. Their complexity varied between 0% and 90% (mean 39.5%, *SD* 20.3). Individual *per participant* task complexity averages varied between 3.3% and 56.4% (minimums 0%-47.3%, maximums 6.7%-90%, *SDs* 3.4-28). Communication tasks are the most common, and support tasks the least common WT type. Table 3 shows the distribution of WT types across WT complexity categories. There seems to be a connection between WT type and complexity.

TABLE 3. WT types and WT complexity (%).

Work task type	**Work task complexity**					
	I *0-21.7%*	II *21.8-38.3%*	III *38.4-50%*	IV *50.1-100%*	**total**	**N**
communication	20.7	28.3	35.9	15.2	100.0	92
support	34.1	22.7	27.3	15.9	100.0	44
editing	26.1	29.0	23.2	21.7	100.0	69
intellectual	13.6	13.6	28.4	44.4	100.0	81
total	22.0	23.4	29.4	25.2	100.0	
N	63	67	84	72		286

The data includes 420 STs. Table 4 shows the distributions of ST feature categories. The *main search media* are quite evenly distributed between organizational databases, the Web and communication media. About 3% of STs occurred mainly on the task performer's PC. Only one search medium is used in most STs (86%) and 99.5% of STs have 1-3 search media, overall average being 1.18. Topical *information needs* form under 20% of STs, factual needs almost a third, and other needs between 20%-30%. Single *search processes* are in the majority (51%), 14% of ST processes are stable, 17% developing, and 18% lists. Moreover, *information need complexity* and *search process complexity* are weakly while significantly correlated (ϱ=.13, p=.008): the more complex the need, the more complex the process.

TABLE 4. Distributions of ST features (N=420).

ST feature	**category**	**% of STs**
main search medium	*pc*	2.9
	org_database	33.1
	Web	33.8
	communication	30.2
	total	100.0
unique search media	*one*	85.7
	more	14.3
	total	100.0
information need	*instrumental*	21.2
	fact	32.6

	known item	28.1
	topic	18.1
	total	100.0
performance process	*single*	51.0
	list	17.9
	stable	13.8
	developing	17.4
	total	100.1

STs and WT complexity

The main search media seem independent of WT complexity (χ^2=4.1, *p*=.902) (Table 5). Organizational databases, the Web and communication media share quite evenly the role of main search medium regardless of WT complexity. The PC always has a share of 2%-3%. Since the independence was surprising, we organized the search media according to their potential flexibility: PC is quite limited in scope since it includes only local programs and files, organizational databases were next, then the Web and last communication media since people as sources of information tend to adapt well to varying information needs. An interesting, small correlation was found between search media and WT complexity. The more complex the WT, the less adaptable media are used (ϱ=-.10, *p*=.041). Communication media reach their smallest share (26%) in the most complex WTs. In the same tasks, organizational databases have the largest share, 36%.

TABLE 5. Main search media (%) in varying WT complexity levels.

		main search medium					
		PC	org_database	Web	communication	total	*n* search tasks
work task complexity	I	1.7	33.9	**35.6**	28.8	100.0	59
	II	2.3	28.7	**37.9**	31.0	99.9	87
	III	3.4	**32.7**	29.9	34.0	100.0	147
	IV	3.1	**36.2**	34.6	26.0	99.9	127
	total	2.9	33.1	**33.8**	30.2		*N* 420

The number of unique search media in an ST is skewed (with 86% of STs having only one medium). This shows that STs are typically well focused. However, the most complex WTs differ from others. Among them, 21% of STs have more than one search medium while in simpler WTs this varies between 10-14%. Figure 3 shows the average number of unique media across WT complexity.

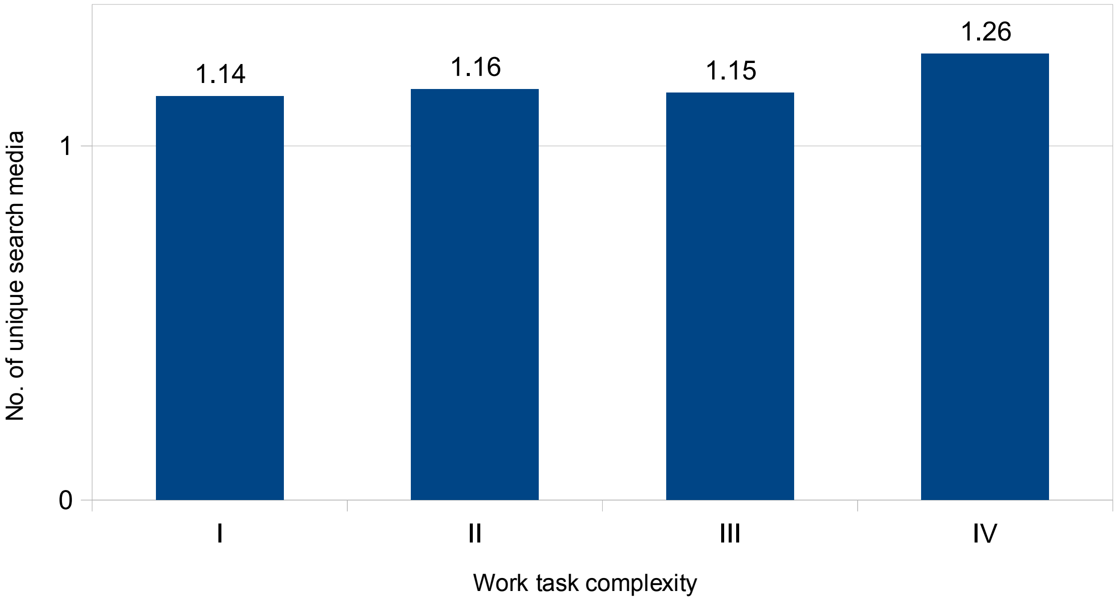

FIGURE 3. The average number of unique search media by WT complexity. Note that the average cannot be <1, since an ST always includes at least one search medium.

The share of topical information needs is at its largest (24%) in the most complex WTs. The share of instrumental needs is at its largest (32%) in the most simple WTs (Table 6). Interestingly, the share of factual needs is similar in the most simple and the most complex WTs. The shares of known item needs seem independent of WT complexity. Information need complexity is independent of WT complexity (ϱ=.07, p=.16).

TABLE 6. Information needs (%) in WT complexity levels.

		information need					
		instrumental	fact	known item	topic	total	*n* search tasks
work task complexity	I	**32.2**	23.7	28.8	15.3	100.1	59
	II	23.0	**40.2**	21.8	14.9	99.9	87
	III	15.6	**38.8**	29.9	15.6	99.9	147
	IV	21.3	24.4	**29.9**	24.4	100.0	127
	total	21.2	**32.6**	28.1	18.1		*N* 420

Single performance processes dominate the data (Table 7); single processes have the largest share in all WT complexity classes. Thus any trends are hard to find between the four task complexity categories and ST performance processes (χ^2=14.1, p=.120). However, the share of developing processes reaches its peak (24%) in the most complex WTs and the single processes reach their minimum share in the most complex WTs. The share of list processes grows a little with task complexity. Performance process complexity is connected to WT complexity (ϱ=.10, p=.037).

TABLE 7. Search process types (%) in WT complexity levels.

		search task performance process					
		single	list	stable	developing	total	*n* search tasks
work task complexity	I	**47.5**	15.3	16.9	20.3	100.0	59
	II	**60.9**	16.1	14.9	8.0	99.9	87
	III	**54.4**	18.4	10.9	16.3	100.0	147
	IV	**41.7**	19.7	15.0	23.6	100.0	127
	total	**51.0**	17.9	13.8	17.4		*N* 420

STs in varying WT types

WT type seems to be connected to the main search medium (χ^2=30.7, p<.001) (Table 8). PC is a rare main search medium but it is most used for searching in intellectual WTs. The use of organizational databases stays quite steady over WT types. The Web reaches its largest share in support tasks (44%), whereas it is seldom used as the main search medium in communication tasks. Communication media are used often as the main medium when searching for information in communication tasks (44%). Communication media are used the least as main media for searching in intellectual WTs (19%).

TABLE 8. Main search media (%) in varying WT types.

		main search medium					
		PC	org_database	Web	communication	total	*n* search tasks
work task type	communication	0.8	34.8	20.5	**43.9**	100.0	132
	support	3.6	27.3	**43.6**	25.5	100.0	55
	editing	2.0	33.3	**35.4**	29.3	100.0	99
	intellectual	5.2	33.6	**41.8**	19.4	100.0	134
	total	2.9	33.1	**33.8**	30.2		*N* 420

STs in all WT types are mostly conducted with one unique search medium. The sum of unique search media over the 420 STs is only 497. In communication tasks, even 95% of STs have only one unique search medium which indicates that searching in communication WTs is especially well focused. Intellectual WTs have the largest number of unique media, more than one search medium in 25% of STs. Figure 4 shows the average number of unique search media across WT types.

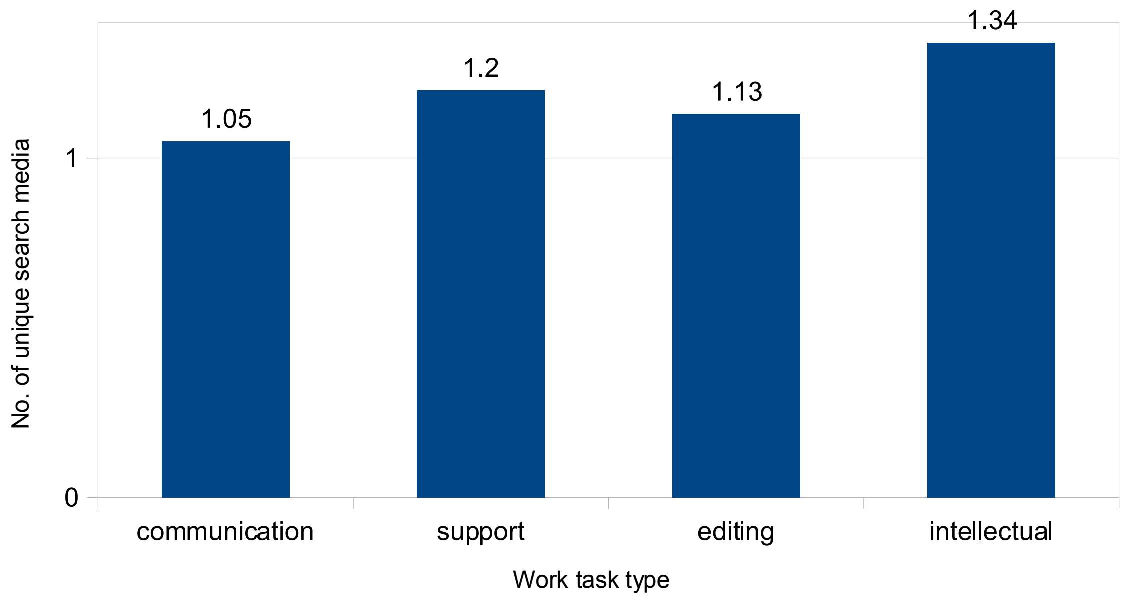

FIGURE 4. The average number of unique search media across WT types. Note that the average cannot be <1, since an ST always includes at least one search medium.

WT type is connected to information need (χ^2=37.3, *p*=.001, Table 9). In communication WTs, instrumental needs are most common and more common than in other WT types, and topical searches are rare. Factual needs are less frequent than in other WT types. Along the WT continuum *sup-edit-int*, the shares of topical and known item needs increase and the shares of factual and instrumental needs decrease.

TABLE 9. Information needs (%) in WT types.

		information need					
		instrumental	fact	known item	topic	total	*n* search tasks
work task type	communication	**31.8**	27.3	25.8	15.2	100.1	132
	support	29.1	**40.0**	21.8	9.1	100.0	55
	editing	22.2	**36.4**	27.3	14.1	100.0	99
	intellectual	6.7	32.1	**33.6**	27.6	100.0	134
	total	21.2	**32.6**	28.1	18.1		*N* 420

WT types are connected to ST performance processes (χ^2=26.0, *p*=.002, Table 10). The trends are not as clear as among information needs. Single processes are the largest class in all WT types, while their share is the smallest, 36%, in intellectual tasks. Interestingly, in support tasks, developing processes are almost as common (22%) as in intellectual tasks (25%). List processes form a fourth of STs in intellectual tasks.

TABLE 10. Search process types (%) in WT types.

		search task performance process					
		single	list	stable	developing	total	*n* search tasks
work task type	communication	**60.6**	12.1	15.2	12.1	100.0	132
	support	**47.3**	16.4	14.5	21.8	100.0	55
	editing	**60.6**	17.2	10.1	12.1	100.0	99
	intellectual	**35.8**	24.6	14.9	24.6	99.9	134
	total	**51.0**	17.9	13.8	17.4		*N* 420

The combined effect of task type and complexity

In this section, we analyze the combined effects of WT types and WT complexity on STs. Here, we classify WT complexity in two classes, simple and complex, by combining the complexity classes I-II, and III-IV (Table 3). Correlation coefficients are calculated between (continuous) task complexity and suitable ST variables within each WT type. Table 11 presents collectively the figures for all WT types, and the results are discussed by WT type.

TABLE 11. WT complexity's effects on STs within WT types.

		WT type								
ST feature	**category**	***Communication***		***Support***		***Editing***		***Intellectual***		
		simple	complex	simple	complex	simple	complex	simple	complex	***total***
main search medium(%)	*pc*	2.2	0.0	6.7	2.5	0.0	4.7	3.3	5.8	2.9
	org_database	22.2	41.4	20.0	30.0	41.1	23.3	30.0	34.6	33.1
	Web	31.1	14.9	53.3	40.0	41.1	27.9	30.0	45.2	33.8
	communication	44.4	43.7	20.0	27.5	17.9	44.2	36.7	14.4	30.2
	total	99.9	100.0	100.0	100.0	100.1	100.1	100.0	100.0	N 420

no. of unique search media	*average*	1.07	1.05	1.27	1.18	1.16	1.09	1.20	1.38	1.18
information need(%)	*instrumental*	26.7	34.5	33.3	27.5	28.6	14.0	20.0	2.9	21.2
	fact	31.1	25.3	26.7	45.0	39.3	32.6	30.0	32.7	32.6
	known item	22.2	27.6	33.3	17.5	19.6	37.2	33.3	33.7	28.1
	topic	20.0	12.6	6.7	10.0	12.5	16.3	16.7	30.8	18.1
	total	100.0	100.0	100.0	100.0	100.0	100.1	100.0	100.1	N 420
performance process(%)	*single*	64.4	58.6	53.3	45.0	64.3	55.8	26.7	38.5	51.0
	list	8.9	13.8	13.3	17.5	14.3	20.9	30.0	23.1	17.9
	stable	13.3	16.1	20.0	12.5	12.5	7.0	23.3	12.5	13.8
	developing	13.3	11.5	13.3	25.0	8.9	16.3	20.0	26.0	17.4
	total	99.9	100.0	99.9	100.0	100.0	100.0	100.0	100.1	N 420
	n of STs	45	87	15	40	56	43	30	104	N 420

Communication tasks

In complex communication tasks, organizational databases are much more common than in simple tasks. In the case of Web use the trend is clearly the opposite. Communication media are used equally often in simple and complex tasks. The number of unique search media, the types of information needs and ST processes respond weakly to WT complexity.

Support tasks

The use of organizational databases and the Web clearly changes with WT complexity in support tasks: The Web is the most common main search medium in simple and in complex tasks, but its share decreases whereas the share of organizational databases increases with growing task complexity. Interestingly, fewer search media are used in complex than in simple WTs. A similar trend can be seen in editing tasks.

In support tasks, WT complexity is negatively correlated with information need complexity (ϱ=-.31, p=.021). Factual needs grow remarkably when WTs become complex: their share increases from 27 % to 45%. The need for known items decreases from 33% to 18%. Editing tasks have the opposite trend with known items.

In complex support tasks, the share of developing searches is as large as in complex intellectual tasks (a quarter), which is remarkably larger than in other task types. The share of developing searches is *clearly* larger in complex than in simple tasks; this is unique to support tasks.

Editing tasks

The shares of main search media clearly change with WT complexity in editing tasks. The use of organizational databases and the Web together in simple editing tasks decreases from over 80% to about 50% in complex tasks. Communication media become prominent in complex tasks: their share increases from 18% to 44%.

In editing tasks the need for known items differs between simple and complex tasks - but in the opposite direction compared to support tasks: in simple tasks, known items form 20% of information needs but 37% in complex tasks. Instrumental information needs decrease from 29% to 14%. WT complexity is positively correlated with information need complexity (ϱ=.24, p=.015).

Intellectual tasks

In intellectual tasks, the use of the Web increases clearly with growing task complexity, whereas the use of communication media decreases. Unlike other task types, complex intellectual tasks include more diverse search media use than simple ones. The share of STs with more than one medium increases from 13% to 28%.

Intellectual tasks show statistically significant connections (χ^2=11.9, p=.008) between WT complexity and the distribution of information needs. The shares of facts and known items remain the same, the share of topical needs almost doubles, and the share of instrumental needs drops from 20% to 3% with growing WT complexity. This shows also in the correlation between information need complexity and WT complexity (ϱ=.23, p=.007): the more complex the task, the more complex information needed.

Complex intellectual tasks have an exceptionally large share (26%) of developing search processes. However, the share of single searches is actually bigger in complex than in simple tasks. The difference is exceptionally clear compared to other task types. The share of stable search processes decreases from simple to complex tasks.

Discussion

WT complexity affects searching

The main search medium and the number of unique search media were quite independent of WT complexity. The most complex WTs, however, had more search media than other tasks. Earlier studies of information seeking (e.g. Byström & Järvelin, 1995; Saastamoinen et al., 2012) show that task complexity affects information source use, but WT complexity seems not to affect the search media used.

A weak correlation suggested that the more complex the WT, the less flexible was the search medium used for searching. This finding suggests that each search medium has varying roles in WTs and thus the flexibility of the information offered is not a good defining feature in this data. Again, search media differ from information sources in this respect, because previous studies (e.g. Byström & Järvelin, 1995) rather show that the more complex the task, the more flexible information sources used.

The share of topical needs peaked in complex tasks. This finding seems straightforward and supports the finding by Saastamoinen, Kumpulainen, Vakkari, and Järvelin (2013). However, the share of topical needs in the most complex tasks is only a quarter; simpler information needs are still important.

In our data, single search processes were most common overall. Exploratory, that is developing processes were most common in the most complex tasks. Our findings partly support Kumpulainen's (2014) conclusion that certain types of processes (trails) are connected to certain task complexity categories.

WT types affect searching

WT type was surprisingly strongly connected to ST features. As the clearest example, all information needs have linear trends along *sup-edit-int* continuum. The shares of topical needs and known items grow, and the shares of factual and instrumental needs decrease following the trends that Saastamoinen and colleagues (2013) found.

Participants across varying work roles and information professions seem to identify *communication* as a separable task type that has to be taken care of on a daily or continuous basis. Communication is normally supporting other tasks (e.g. no emails written *per se*) but considered more than a mere support task. Table 3 suggests that communication tasks are between intellectual and editing tasks regarding their complexity.

Task types versus complexity

We suggest that task type and complexity augment each other and should be analyzed together. In the present study, task complexity was calculated as an average of numerical estimates given by the participants, whereas task types were classified by the researcher based on the written, open task descriptions. Therefore WT complexity was rather subjective, whereas WT type was somewhat more objective. At least task types were selected using the same criteria for all tasks but each participant may have had their own understanding of complexity criteria.

Growing task complexity seems to increase the need for new information, whereas task type seems to be connected to the type of the information needed: in support tasks, factual needs grow rapidly from simple tasks to complex tasks, whereas the same happens to topical needs in intellectual tasks. However, the apparent complexity of the STs does not necessarily correspond to the complexity or type of the underlying WTs.

Without a doubt, in communication tasks, communication media are as important regardless of task complexity. In support and editing tasks, communication media are used more in complex than in simple tasks, which may reflect the need for flexible information. Surprisingly this does not hold true for complex intellectual tasks where communication tools are rarely the main search media. It may be that complex intellectual tasks must be performed individually and consulting other people would not help – especially in case of complex tasks - as intellectual tasks are at the core of one's own expertise. Intellectual tasks in our data were mainly writing tasks where the participant was the expert herself; and not extensive decision tasks that have been of much interest in earlier studies (see for example the review by Li and Belkin (2008)). These findings may depend on the work roles of the participants. On the other hand, we did not analyze non-computer mediated information interaction which may have taken place in all task types; perhaps performing complex intellectual tasks demanded face-to-face support from colleagues.

About real-life searching

Our point of departure was that since WTs are building blocks of information-intensive work, they must also affect STs, an integral part of these WTs. Because real-life studies on this scale are rare, there was no basis for hypothesis formulation and testing. Both methodologically and research question-wise the present study belongs to the same category as the studies by Hansen (2011), Saastamoinen et al. (2012) and Kumpulainen and Järvelin (2010).

STs were mainly simple: the majority consisted of a single query in a single search medium while the media differed between tasks. Ingwersen and Järvelin (2005) postulated that simple, organized practices supply most of the information needed in work. It seems important to develop systems to serve also simple STs effectively and efficiently, but the tasks in IIR experiments typically represent complex, search-intensive tasks. Often they are not even WTs but related to leisure time or other non-work issues. To start with, further studies are needed to find out how more typical WT scenarios could be exploited in IIR research.

Limitations

The present study was an explorative real-life study, and its data set was rich but initially rather unstructured. It had to be processed manually in many phases, and categorizations and decisions were made intellectually from the start. The decisions were based on all available data, including the transaction and video logs.

Since we wanted to maximize the validity of the study, we used as much of the data as possible; that is, chunks of data were discarded only for strong reasons. This approach differs from laboratory studies and other studies conducted in controlled environments where the internal integrity of data is highly valued and only perfect logs, for example, are accepted for further analysis. Some data was missed if the participants occasionally forgot to start the recording or to save it; or wanted videos to be blurred or cut for confidentiality reasons.

However, it was possible to reliably reconstruct the missing parts of the searches. This was possible because there was plenty of data regarding similar search situations. We could also triangulate the missing data using the available data subsets. We analyzed the distribution of the augmented data and how it affected the results, and nothing questioned our approach of augmenting the data.

Our study was rather ethnographic, which challenges its repeatability. This is the price one must pay when studying humans in their natural environments. The risk is worth taking if one wants to understand these phenomena better in order to design new kinds of more structured studies and to innovate new kinds of information systems.

It is possible that there are other factors that affect information searching indirectly besides WT complexity and WT type. Our data suggests that task complexity distributions may vary by organization type. Further analysis of the effects of organization or other contextual factors was beyond our research questions and is left to future research.

Conclusions

In this paper, authentic search tasks (STs) were empirically studied in the context of authentic work tasks (WTs). This type of research is rare in the field of information seeking and retrieval. ST - WT interactions were analyzed statistically using information needs, ST processes and search media as dependent variables, and WT type and complexity as independent variables.

It was found that WT type may have clearer connections to STs than WT complexity, and that most STs are simple, i.e., including only one query in one search medium despite WT complexity or type. The studied authentic WTs do not much resemble the so called simulated WTs used in past studies. Similarly, neither do the authentic STs much resemble test tasks applied in user studies in interactive information retrieval because the information retrieval part of authentic work is inseparable from its other subtasks.

The present study may help assess the applicability of experimental STs used in future research. The main question for the future is whether information systems and information retrieval features are to be developed to support all kinds of STs/WTs or only some task types. This includes the questions of whether to concentrate on complex/intellectual WTs where information needs are more vague, or to include other kinds of tasks, as well.

This paper contributes to the knowledge of authentic information searching. The findings can be used to design more realistic experiments in future, to better understand what information searching is about in real-life contexts, and therefore guarantee validity of experimental information search studies.

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Appendix 1: Morning questionnaire

What WTs do you have to perform today? Base your replies on your present knowledge.

<u>Contact information</u>

Name:

Organization:

<u>Tasks</u>

[The questionnaire includes place holders for 5 tasks. The participants fill in as many tasks as they need to. For each:]

The WTs of today. Task complexity should be given as a number 0 (really simple)-100 (really complex).

Task description:

Task complexity 0%-100%:

Task performance. You should answer with a number 0 (not at all)-100 (perfectly) to the question of how well you know the task performance process.

Programs/information systems needed:

Other information/sources of information needed:

How well do you know the task performance process?:

Other remarks (e.g., about the tasks or the course of the day):

Appendix 2: Afternoon questionnaire

What WTs did you perform today? Think about the whole working day from the morning to the afternoon as you reply.

<u>Contact information</u>

Name:

Organization:

<u>Tasks</u>

The WTs of today. Task complexity should be given as a number 0 (really simple)-100 (really complex).

[The questionnaire includes place holders for 5 tasks. The participants fill in as many tasks as they need to. For each:]

Task description:

Task complexity 0%-100%:

At what time (approximately) did you perform the task? (E.g., 12-13)

Task performance

Programs/information systems you used:

Other information/sources of information you used:

Did any problems turn up in the task? Please describe them.

Other remarks (e.g. about the tasks or the course of the day):

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Queries in authentic work tasks: The effects of task type and complexity

Abstract

Purpose – This paper investigates information retrieval (IR) in the context of authentic work tasks (WTs), as compared to traditional experimental IR study designs.

Design/methodology/approach – The participants were 22 professionals working in municipal administration, university research and education, and commercial companies. The data comprise 286 WTs and 420 search tasks (STs). The data were collected in natural situations. It includes transaction logs, video recordings, interviews, observation, and daily questionnaires.

Findings – The analysis included the effects of WT type and complexity on the number of STs, queries, search keys and types of queries. The findings suggest that simple STs are enough to support most WTs. Complex WTs (versus more simple ones) and intellectual WTs (versus communication, support and editing WTs) include more STs than other WT categories.

Research limitations/implications – Further research should address the problems related to controllability of field studies and enhance the use of realistic WT situations in test-based studies, as well.

Originality/value – The study is an attempt to bring traditional IR studies and realistic research settings closer to each other. Using authentic WTs when studying IR is still rare. The representativeness of the WT/ST types used in interactive IR experiments should be carefully addressed: in the work flow, people seldom consciously recognise separate 'STs'. This means that STs may mainly be an academic construct even to the point that studying IR without a decent context does violence to the further understanding of the phenomenon.

Keywords Information retrieval, WTs, Searching, WT complexity, Queries, Field studies

Paper type Research paper

Introduction

Many jobs and tasks have information use and knowledge creation at their core. Knowledge work has a number of descriptive features; it is hard to delimit to comprise only some professions. (Pyöriä, 2005). The tasks of teachers, researchers, human resource experts and financial managers differ in their contents but they also share several features such as the varying degree of complexity, urgency and salience, and varying types of the final output or outcome (see, e.g., Li and Belkin, 2008). Knowledge work is formed of work tasks (WTs) that are building blocks of one's job (Byström and Hansen, 2005). In the present study, WTs are understood as concrete sections of time that include actions to proceed towards a goal, the task outcome.

Information retrieval (IR) as a practical activity supports task performance in authentic environments. However, much of IR systems development takes place through laboratory experiments using test collections. While traditional test-collection based IR evaluation studies are relatively easy to execute and serve the development of IR methods well, they are not quite sufficient to learn about IR effectiveness in authentic environments. Without studies of authentic use situations, studies based on simulated WTs or narrower search tasks (STs) conducted in a laboratory remain only as hypothetical approximations of the situations. Effective IR systems, or other information systems, should not be designed solely on such a basis. (Vakkari, 2003.) IR systems and methods are studied and developed continuously (see, e.g., Ruotsalo *et al.*, 2013) but as a real-life phenomenon, bound to its context, IR has not been of much research interest (Järvelin *et al.*, 2015; Vakkari, 2003). Traditional server-side log analyses are perhaps adequate when developing a single search system; but they are not enough when developing the information environment or the ways of acting in it.

The purpose of the present study is to analyze IR conducted in real life in connection to WTs. WTs are categorised by their complexity and type and they act as the context in which IR is performed. The dependent variables representing IR are the number of STs, the number of queries, the number of search keys and the query types. The study is explorative and quantitative. The main data consist of client-side transaction logs and screen videos that are supported by electronic questionnaires, interviews and observation. This study is one of the few studies so far that aim at capturing authentic IR in context of authentic WTs with objective real time data collection methods. These kinds of investigations are important in order to understand what IR is used for, how it is performed and what factors affect it. Otherwise the refinement of search engines and designing of user tests are based on mere assumptions that may or may not add to the actual usefulness of information systems. The present paper focuses on the query aspects of the rich data set. The results concerning information needs, search media and information search processes are reported elsewhere (Saastamoinen and Järvelin, in press) for conciseness and readability of the paper.

Related research

In this section, earlier research on IR, STs and WTs are discussed. This includes empirical, theoretical and methodological points. WTs and STs are the two most important concepts of the present study, since it concerns the effects of WTs on IR which is organised into STs. IR studies on the one hand and studies on WTs on the other are many. This selective literature review is meant to a) give an overview of tasks as theoretical constructs in IR and information seeking research; b) discuss the concept of task complexity within these fields; c) present earlier empirical findings and methods that connect task features to IR and aim at realism and validity in the study design. Especially the point c) narrows the empirical focus of the section and excludes a vast body of information seeking studies, IR laboratory studies and survey studies as non-relevant to the approach of the present paper. Vakkari's (1999) review is recommended to the readers interested in older studies about the subject.

The underlying tasks are important starting points of IR research as stated by, for example, Kuhlthau (2005) and Vakkari (1999). Byström and Hansen (2005) name two conceptions of *WTs* as study objects. WTs can be abstractions as defined in task assignments, or concrete steps taken in order to proceed (Byström and Hansen, 2005). The latter view is applied in the present study. WTs contain subtasks (Vakkari, 1999). One subtask type is *information STs*. Based on earlier research, it seems that WT is becoming an increasingly acknowledged context of studies in IR. However, the term 'WT' is used synonymously to STs in some studies.

IR and tasks are highly interconnected as shown by several studies. Järvelin (Ingwersen and Järvelin, 2005; Järvelin, 1986) presented a model for information access where task goals, task processes, the needed and used information, information searching, as well as information systems are bound in a complex interaction and mutual adaptation. The results of the empirical study by

Pharo (2002) interestingly suggest that IR may even affect larger task goals, not only the other way round. Pharo (2004; 2002) also states that WT goals are directly connected to the criteria of relevance assessment. Similarly, Vakkari (2001, 2000) has shown that task performance stages are connected to the type of needed information, search terms, tactics and relevance criteria.

Since the seminal paper by Byström and Järvelin (1995), *task complexity* is a widely recognized task feature that can affect task performance and information seeking. Task complexity is related to, for example, task difficulty, task extent and the performer's level of knowledge. The concept is, however, used differently in different studies. The operationalisations vary, and sometimes task complexity is understood as *ST complexity*, sometimes as *WT complexity*. (Liu and Li, 2012; Wildemuth *et al.*, 2014.) Authentic WT complexity's effects on IR, such as the number of search terms and types of queries, have not been systematically analysed in past studies. The present paper analyses only WT complexity, but research discussing ST complexity is also a noteworthy reference point. Thus both are discussed below.

A dichotomy is often made between task complexity’s *objectivity* and *subjectivity* (perceived complexity). In reality, these two are connected. Liu and colleagues (2015) controlled objective ST complexity (operationalised as the number of activities and information sources needed to succeed in the task) in an experiment and found that these complexity features are connected to the post-search difficulty estimated by the participants. Hansen (2011) found that some WT types in a patent office are often perceived to be difficult. Tasks that included handling patent applications in their early form were considered mostly difficult perhaps because of the low amount of case-related information available (Hansen, 2011).

Bell and Ruthven (2004) tested the relations between objective and perceived (subjective) ST complexity. They found that perceived task complexity is linked to how much and what types of information are required in the task assignment. Perceived task complexity was also affected by how clearly information requirements were stated in the assignment and how well they were understood by the task performers. (Bell and Ruthven, 2004.) However, in real-life situations, the issues concerning the task performer’s ability to understand ST assignment may be of minor importance, depending on the profession. STs following information needs are often internally generated during the flow of a WT rather than ready-made for the task performer. Furthermore, even if the ST was externally generated, the task assignment does not have to be identical to the information needs it generates. The task performer may have the option to use several resources to complete the task and even the option to ask for further instructions from the initial ST generator, which may not be possible in a test situation.

Expertise or the amount of *knowledge* has connections to task complexity and task performance in interesting ways. Vakkari (2001) proposed a theory of task-based IR which is based on his longitudinal study on students’ IR processes and Kuhlthau’s (1993) information seeking model. The theory shows that task stage is connected to, for example, the number and type of search terms used. (Vakkari, 2001.) Though Vakkari’s (2001) theory explicitly discusses the stage of the task, that is the amount of knowledge the participants have, it is parallel to perceived complexity of perceived WTs: A WT, understood as a process within a longitudinal work duty, always has a stage dimension and prior knowledge which are reflected in the task performer’s estimate of perceived complexity.

Haerem and Rau (2007) analysed the connections between objective task complexity and expertise. They defined objective task complexity based on whether a programme coding problem can be most efficiently solved by modification of the surface level (inputs and outputs) or by modifying the underlying process of the task (or both). They found task complexity an important factor in task performance. In their study, participants had different levels of *expertise* suitable for assigned programming tasks at hand. It was found that experts and novices may literally see tasks differently depending on task complexity. Novices even outperformed experts in objectively simple tasks because their superficial knowledge was suitable and enough for successfully performing the task. (Haerem and Rau, 2007). Similarly, the findings of Vakkari and colleagues (2003) suggest that *domain knowledge* affects information searching if the participants have enough system knowledge as well. Hansen (2011) found in a patent information interaction study that low *domain knowledge* leads to the use of fewer search terms. Saastamoinen, Kumpulainen and Järvelin's (2012) findings suggest that with increasing subjective WT complexity, the number of queries per WT increases. Task complexity predicted some information searching phenomena better than others, and actually perceived complexity seemed to affect WT performance more clearly than *a priori knowledge* of the task features. However, a priori knowledge was also measured subjectively (Saastamoinen *et al.*, 2012).

Marchionini (2006) differentiates between *exploratory STs* that are connected to the aims of learning and discovering, and *lookup searches* that are for example factual searches or searching for known items or other well-stuctured or well-known objects. Exploratory STs can actually be considered complex STs (Wildemuth and Freund, 2012). Wildemuth and Freund (2009) call for a definition for exploratory searching. They state that explorativeness is formed of several factors, such as generality, need of several documents and some sort of overall obscurity (Wildemuth and Freund, 2012).

Ruotsalo and colleagues (2013) studied university students and staff performing assigned *exploratory STs* whose idea was to find relevant scientific papers on given subjects. Their results indicate that, compared to only typing queries, participants gained a lot of benefit from using a system, which visualised the search and enabled direct control over the importance of each key word (Ruotsalo *et al.*, 2013). Unfortunately, the study concerned only exploratory STs. It would have been interesting to see whether a highly interactive search system supports different types of tasks in distinct ways; that is for example when searching for facts or known items. Though lookup searches are often important in daily searching, IR systems should support more explorative needs as well (Marchionini, 2006). Lookup and exploratory STs are compared, for example, by White and Marchionini (2007). They found that explorative searching includes using more unique query terms per task (White and Marchionini, 2007).

Varying empirical approaches to authentic information retrieval

Collecting anonymous search logs from search engines is an efficient way to get a large data set. Though quantitatively pre-eminent, these data do not include any explicit information about the information needs or tasks of the person behind queries. A good review of past log studies and a presentation of ways to exploit logs is found for example in Silvestri (2010) and Jansen (2009).

A typical way to study interaction between users and IR systems (called interactive information retrieval, IIR) is to conduct a user study in controlled settings (see, e.g. Kelly, 2009), often using *simulated WTs* that were proposed by Borlund and Ingwersen (1997; Borlund, 2003). Test settings enable systematic control over some features (*i.e.* independent variables) while studying their effects on participants' task performance. For example, Ruotsalo and colleagues (2013) conducted a rather typical user test.

The STs or simulated WTs tend to be used in studies without actually knowing their validity. Li and Hu (2013) tested on a small scale whether performing a simulated WT differs from performing an authentic task. The authors concluded that simulated WTs and authentic tasks did not differ essentially in task performance or participants' perceptions of the tasks, but that this holds only if simulated WTs are carefully designed regarding task complexity and relevance (motivation) to the participants. (Li and Hu, 2013.) This is also the original idea behind simulated WTs by Borlund (2003). Though Li and Hu's (2013) study was a fair attempt to empirically address question, it had some validity issues: The participants were undergraduate students, they were allowed to use only one information system, and the simulated WT seemed quite difficult in the short 15 minutes they had to accomplish it.

Vakkari's (2001) longitudinal study combined features of a controlled user study and naturalistic approach. The participants were students writing an authentic research proposal. During a four-month period, they had three sessions where they searched for relevant documents. The participants were interviewed, they were asked to think aloud while searching, and transaction logs were collected. The participants also assessed the relevance of the documents found. Between these search sessions, they were keeping diaries about their progress in the task. (Vakkari, 2001.) Similarly, Pharo (2002) combined controllability and authentic study assignments in his study: the participants contacted the researcher when they wanted to search the web for their theses. The participants were interviewed for their tasks, and their search sessions were recorded on video and observed. Combining controllability and authentic tasks is a potentially fertile and valuable approach. However, these studies only included a small number of students as participants. The participants had only one, quite large and demanding task to perform in somewhat artificial situations. Despite the inherent complexity of the task in question, IR was logged from the perspective of using a single information source; a bibliographic database or the web.

The field has a limited number of studies on authentic larger tasks' effects on IR (see e.g. Kellar *et al.*, 2006; Kelly, 2006; Kumpulainen, 2014). Or, if authentic work is studied, the data are often self-reports by the participants, that is interviews (Li, 2009), diaries (Du, 2014; 2012) or questionnaires that often involve *ex post facto* rationalisations and other limitations on the data. Traditionally, studies of information seeking or other information practices (e.g. Lingel, 2015; Robinson and Yerbury, 2015) do not discuss IR in detail, such as queries. Nicholas and colleagues (2010; 2009) combined questionnaires, interviews and observation to log analysis when studying information seeking and IR of researchers. A problem was, however, that the logs could not be linked to the participants of the survey; the people searching and telling about their searching were similar but likely not the same (Nicholas *et al.*, 2010).

Hansen (2011) conducted a thorough study of patent engineers' information seeking and IR behaviour. His data contained interviews, observational data, electronic diaries and interaction logs. Saastamoinen and colleagues (2012) studied municipal workers' information searching. The data were collected observing authentic WTs with varying perceived complexity (Saastamoinen *et al.*, 2012). Xie (2000) conducted a field study of library users. She used interviews, logs and observation to find out how the participants shift in their strategies and information goals while seeking for information. However, the study only analysed the shifts, not the factors affecting them (such as task complexity). (Xie, 2000.)

In summary: STs in real life are part of larger tasks and thus more evolving and endogenous than assigned test tasks. It is possible that short, clearly targeted IR sessions in a single system are somewhat similar in real life and in simulated situations. This would encourage evaluation studies using assigned STs. However, such tests can be far away from authentic WTs where several systems can be used side by side, dead-lines can vary and people actually use information and documents after finding them – i.e. when IR is not an end in itself (Järvelin *et al.*, 2015). Naturalistic studies are resource-intensive because they mean letting participants do their own work, their own tasks, with their own information resources and collecting simultaneously data about their tasks, information resources and IR. This may be considered prohibitive. Naturalistic studies are nevertheless necessary: they provide invaluable knowledge about the phenomena studied. This knowledge can be used to design more effective and realistic laboratory and user studies.

Research design

This is a descriptive and explorative study presenting empirical findings concerning task-based IR. Since there was no ready-made methodological toolkit to be used in the study, the study also contributes to the methodology within the field. The purpose of the paper is to improve the research community's understanding of authentic IR, especially queries, in task context. This is important because a) the understanding can increase realism in user tests; b) querying is related to the effectiveness of IR; and c) better knowledge facilitates improving effectiveness of information systems, their user interfaces and ways of use. The present paper discusses the query features and the number of STs in WTs.

Research questions

The research questions are as follows:

1) How is WT complexity connected to IR features?

2) How are WT types connected to IR features?

3) How is WT complexity connected to IR features within each WT type?

The *IR features* discussed in the present paper are (a) the number of STs in WTs; (b) the number of queries in STs; (c) the number of search keys of queries in STs; and (d) the types of queries in STs. *WT complexity* means here perceived complexity, an aggregated variable formed of subjective estimates given by the participants. *WT types* form an *ad hoc* categorisation based on the present data set. The categories are communication, support, editing and intellectual tasks. The IR features, WT complexity and WT types are defined below.

Data and data collection

Next, the data and the data collection process are presented. The exact figures of data are presented in Table 1. A total of 22 subjects working in six different organisations participated in the study. Note that these six organisations of three organisation types were a convenience sample. The participants were 17 females and 5 males between their mid-twenties and mid-fifties; three of whom were in managerial positions. The participants' WTs and information sources are briefly discussed below in order to give the reader an understanding of the organisations in question. However, please note that the differences between these organisations are not analysed further but their data are merged.

Table 1. The profile of the data set.

Organisation type	Organisations	Participants	Days	Work tasks	Search tasks
Municipal administration	1	10	10	47	55
University	3	5	30	101	173
Company	2	7	37	138	192
Total	6	22	77	286	420

In municipal administration, the participants worked in the sectors of communication and human resources. They used several internal databases to find, *e.g.,* people and decisions. In addition, they used the organisation's intranet in order to stay up-to-date. Several of these participants had WTs that involved updating the organisation's intranet or external website.

In the universities studied, the participants had research and teaching related WTs as well as small administrative tasks, such as filling in working hours in an electronic system. The systems they used included library catalogs, electronic libraries, dictionaries and powerful scientific calculation programmes. Teaching included planning courses and lectures as well as assessing study assignments on electronic platforms.

The participants in the companies had varying roles and tasks. They worked for example in design and supply of consumer goods and services, marketing, financial administration and data administration. These tasks typically included making decisions as well as typical administrative tasks. The key information was found in several internal databases but extra-organisational information was also searched in the web.

The majority of participants, 12, were asked to participate for five working days, although more was allowed and also welcomed. The municipal administrative organisation, with 10 participants, had only one working day in the data per person. This was due to practical issues discussed and agreed with the organisation.

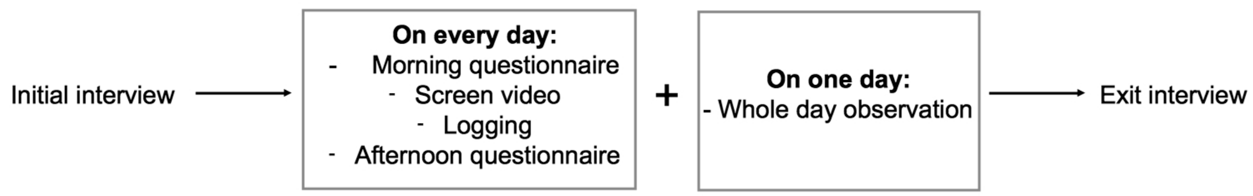

Figure 1. The data collection methods.

The first author of the paper performed all data collection. Several data collection methods were used (see Figure 1). This enabled triangulation of the data. An *initial interview* was held in order to get general information about the participants' working role, their tasks, the information systems they used and their overall information searching behaviour. After the data collection of each participant, the researcher made preliminary analysis on the data. After that, an *exit interview* was held with those participants, who had data for several days. The purpose of the exit interview was to clarify possible unclear parts in the data to the researcher. All interviews were held individually with each participant.

During all actual data collection days, the data were collected through transaction logging, screen capture video and questionnaires. In the morning of each day, the participants were requested to list in an *electronic questionnaire* the tasks they thought they are going to perform that day. They also estimated the complexity of the tasks in the questionnaire. At the end of the day they described their tasks similarly and stated how complex the tasks felt afterwards. (See Appendices for the questionnaires.)

A *screen video recorder* and a *logging programme* were installed on the primary computer of each participant. The logging software started recording automatically but the participant had to start the screen capture and switch it off. Logging could also be stopped and re-launched. The participants were advised to inform the researcher if there was something they did not want to be recorded. If they afterwards wanted something to be removed from the video or the logs, the passage in question was either cut or blurred so that all texts became unreadable. In addition, one data collection day included *observation* conducted by the researcher. All participants were offered a small-scale feedback describing their personal information searching behaviour or the overall results concerning the organisation in question; and the ones that had participated for several days also got movie tickets as an appreciation of their efforts.

Analysis

The WTs that the participants named in the daily questionnaires were accepted for further analysis if these tasks were recognisable in the log or in the videos or both. This means that tasks actually not performed, while planned to be performed in the morning, were naturally excluded as well as tasks where the computer was not used at all (some meetings, for instance). After data categorisation, the variables were analysed quantitatively. In the Findings section, the mean, median, Spearman's correlation marked with ϱ (rho), its statistical significance marked with *p,* and distributions are discussed. The generally accepted limit $p<0.05$ is used for statistical significance. Statistical significance guides but does not strictly limit the interpretation of correlations.

WT types and complexity

Each WT was assigned a complexity estimate and task type. These are defined below. *WT complexity* refers to perceived complexity, that is, the subjective view of the task performer. Task complexity is simply the average of three percentage estimates (0%-100%) given by the task performer. One is the task complexity estimate given before the task, the second is the estimate given after the task, and the third is the complement percentage of participant's knowledge of the task process asked in the morning questionnaire. The last one means that the more the participant knows, the simpler the task; that is if she knows, e.g., 80 % of the task process, the complexity estimate based on this figure would simply be 20 %. If any of the three estimates was missing, the average was calculated of the estimates that were available. In total, 22 % of all potential estimates were missing, for instance due to participant's carelessness or an unforeseen task being performed.

The operationalisation of task complexity is adapted from earlier research (Saastamoinen *et al*., 2012; Byström, 1999; Kumpulainen, 2014). Three task complexity estimates (pre-task, post-task and knowledge of task process) are chosen instead of one in order to increase the validity of the task complexity estimate. There is no reason to predict that one of these estimates would alone be more valid than others; they represent different aspects of WT complexity.

Continuous task complexity was used as the base for categorising complexity. WTs were categorised in two different ways into complexity classes. In one, the complexity classes are in 10 % intervals (i.e. tasks from 0 % to 9,99 % complexity and so on). This is the one used when calculating correlations. In the other categorisation, the WT complexity is divided into four classes so that each includes about one quarter of the WTs; I (tasks from 0% complexity to 21,7%), II (21,8-38,3%), III (38,4-50%) and IV (50,1-100%). Four classes are used for calculating the mean and the median. The categorisations are here called *equidistant* and *equal-number categorisations*, respectively.

The ways of categorising task complexity are based on extensive initial analysis of the data. Categorising the complexity was a necessity in order to calculate descriptive figures. Using categories of approximately same sizes (equal-number categorisation) is an established statistical solution to get reliable analytical results. The previous experiences (Saastamoinen *et al*., 2012) dividing tasks to only three categories showed the problematic interpretation of the middle category that was neither complex nor simple. Four categories enable summing up the data into complex and simple half when necessary. Using five categories was also tested but it was not found more useful than a four-category solution. The connections between WT complexity and IR features in this real-life data are seldom clearly linear; using too few categories leads to no variation between categories, and using too many leads to difficulties in finding the overall trend between several figures.

The equidistant categorisation maintains enough detail of the original complexity estimates but tidies up a little the variations found, and makes the distribution of WT complexity near normal. Equidistant complexity represents the absolute perceived complexity of the tasks, whereas the equal-number categorisation proportions the complexity of each task to other tasks (simple, semi-simple, semi-complex and complex) exploiting information about data distribution. It was necessary to use these ways of categorising task complexity because they allow complementary analyses. The categorisations were chosen following basic principles of quantitative analysis. Also a qualitative counterpart to task complexity was used, task types, which are explained next.

The researchers formed a *WT type classification* to all WTs in the data. The task type classification is based on written descriptions of tasks given by the participants. It is another task dimension that complements task complexity so that the possible effects of task complexity on IR could also be compared to another meaningful independent variable. The task type categorisation is data-driven while abstract and therefore usable across the tasks of the organisations studied. Four types of tasks were found in the data set: communication, support, editing and intellectual tasks. Note that since these task types were data-driven, the labels and descriptions were formed *post hoc*.

Communication tasks require distributing and/or receiving information. These tasks typically include handling email or discussing with colleagues in a meeting. Real time teaching is also considered as communication task.

Support tasks are tasks that support the main tasks of the organisation. Typically, the process of these tasks is well-defined: they do not include a creative process *per se*. Support tasks are such as accounting and filling in structured forms.

When performing *intellectual tasks*, the participants create something new, either in the sense of a concrete output or creating knowledge. Also solving significant problems is counted into intellectual WTs.

Editing tasks are similar to intellectual tasks, but they often heavily build on some previous work by the task performer herself or others thus being ”semi-intellectual”. They can also be described as parts of doing some bigger tasks, such as starting or finishing something. Editing tasks have clear hints of incompleteness, partial work or the editing phase in the task description so they were quite easily recognisable, such as going over some new instructions and commenting on them, or to start writing a memorandum.

In support tasks, information is often handled as an object in the sense that it does not and is not intended to turn into ’knowledge’ but rather moved, applied in a straightforward manner, or mechanically revised. These tasks are simple in interacting with information content. In editing and intellectual tasks, people generate new information and knowledge. The output may be formal, such as an essay, or the information gained is used in order to create new knowledge to support decision making or to solve a problem the task performer has. The difference between editing and intellectual tasks is that intellectual tasks require more intellectual input as something is done from scratch; editing tasks are ‘partial’, for example the task performers build on an existing base.

Support, editing and intellectual tasks can be seen as forming one interpretation of task complexity. Communication tasks cannot be inherently included in the continuum. However, task types and task complexity are, by definition, independent of each other in the present study. Task types are based on labels given by the participants and categorised by the researcher, whereas task complexity is an average of numeral task complexity estimates given by the participants.

Two researchers from the same research center reclassified a random subset of tasks. They had the same brief descriptions of the task types as presented above. The first one knew the study but had not handled the data. He classified 82 % of tasks to the same categories as the original classifier. The other reclassifier did not know anything about the study beforehand. The similarity of his and the original classifier’s decisions was 74 %. The intra-classifier reliability was 88 %. Cohen’s Kappa for inter-classifier reliability was 0.69, for intra-classifier 0.83.

Information STs

An ST is a temporally continuous (i.e. two STs cannot overlap) subtask that includes a query or queries and has a somewhat uniform motivation (”an information need”) to search for information. Thus, STs are not self-standing search assignments as in IIR experiments but materialised processes judged afterwards. This is one reason for the decision that STs cannot overlap; in the definition applied here, there do not exist self-standing, abstract information needs that could be returned to.

Instead, information needs are formed seamlessly in the work flow as a motivation to conduct the immediate concrete search actions. Although STs cannot overlap each other, a random interruption, such as an incoming call, does not necessarily break the ST. The latter happens only if this call, *e.g.*, results in a recognisable switch of WTs in the logs. In practice, finding the technical boundaries between STs was not an issue. Most often STs were quick and imminent. It was utterly rare that an identical ST (*i.e.*, information need as defined here) would continue after performing another search or WT.

While the above ST definition may seem loose, information STs as understood in laboratory-like settings seldom have a clear equivalent in real life. Even if they had, a pre-constructed ST in a laboratory still remains an experimental artefact, whereas what people do in their work places is an IR phenomenon that is strictly dependent on the task at hand. In the field, people did not seem to analyse or plan their STs; there were no explicit traces of planning in the data. A query was issued in an information system if it was considered the optimal solution for the current information need. As the main purpose of the present paper is to describe real-life IR, the IR features to be studied had to be selected based on the data so that they are reliably analysable, potentially responsive to WT features, and of general interest in the IR community. Knowing the distributions of these IR features helps design and calibrate IIR experiments, for instance based on simulated WTs.

In the present paper, four IR features are analysed:

1 *The number of STs in a WT.*

Motivation: To understand if some WT categories involve more searching than others and why.

2 *The number of queries in an ST.*

Motivation: To understand if some information needs take longer, or require multiple approaches, to be fulfilled and why.

The queries need not be unique; the searcher may as well type an identical query several times in different information systems or even in the same system and they are all counted. In reality, repeated queries in a single ST were rare, so the practical importance of this decision is small. However, for the searcher herself, a repeated query is as important as a unique one. Thus, there is no need to consider only unique queries here. A typical repeated query was, for example, a search for a translation of a word while reading a text. The word may recur after a while and it is not uncommon that the participant already forgot the meaning and has to search again.

3 *The median number of search keys*.

Motivation: Query length may reflect the vagueness vs. clarity of information needs.

The number of search keys in each query of an ST was calculated and a median was taken across the queries in each ST. The number of search keys was calculated manually; space acted as an absolute word boundary and also other punctuation marks if they separated two words as judged intellectually. Also clear filtering conditions were calculated as search keys, such as selecting a retail chain from a drop-down menu (cf. point 4). The median was used instead of mean because it is not so sensitive to a few extremely long queries in the data.

4 *Query type*.

Motivation: Query types may reflect the clarity of the information need which may further reflect the features of WTs.

Query types are intended to describe the exactness and versatility of queries in STs. Each query belongs to one of the following, mutually exclusive types: *v* (predefined attribute value), *f* (figure), *c* (common noun) or *p* (proper name). First, if the query is performed without any freeform typing of search keys, it is of type *v* (e.g. using only drop-down menus). The remaining query types are freeform to some extent. Second, if the search key is only a figure, the query type is *f*. 'Figure' includes here both numerical sequences and pictorial queries; however, the only "pictorial queries" in the data were searching with molecular structures. Third, queries including common nouns form type *c*. If a query includes at least one proper name, it is judged 'specific', that is, it belongs to the fourth type, *p*. A query is of only one type but an ST having several queries can include several query types, respectively. Query types are analysed as binary variables. Each ST therefore either has or does not have queries of each type (*v, f, c, p*). The number of different query types can range from 1 to 4. An ST gets value *c*, if all queries in it are type *c*, *cp* if some queries are type *c*, some *p*, and so on. Thus the most varied ST could be *vfcp*; it should have at least four queries, all of different types.

Below are some examples of query types in authentic STs:

- *v*: Selecting attribute values in various search fields in an internal database without typing any free-form query terms, such as when searching for sales figures. Typical attributes in the present data set are a geographical district, a specific store, and time period.

- *f*: Checking product information in order to reply to an email. Three queries are typed in an internal database: first, an identification number of purchase, then a product code, and last, another identification number of purchase. These are all type *f* because they are typed numbers only.

- *c*: Searching for a fact in a general web search engine using query 'malonate'.

- *p*: Searching for a scientific article in a public web search engine. The query is formed of the name of the article, the writer's last name and a predefined attribute of estimated publication years. Because there are typed proper names involved, the query is of type *p*.

Results

Overall view of the data

Altogether 286 WTs were identified in the data. Their complexity varied from 0% to 90%, the mean being 44%. Task complexity was roughly normally distributed. Communication tasks formed 32.2 % (92 tasks) of the data, intellectual tasks 28.3 % (81) and editing tasks 24.1 % (69), respectively. Support tasks were the smallest category with 15.4 % (44) of the tasks. The 286 WTs contained in all 420 STs. However, 42 % of WTs did not include any STs. The maximum number of STs in a WT was 13, the next to maximum 11 STs.

Overall, STs are quite simple considering the features analysed in this study (see Figure 2). Over one half (51 %) of STs consists of only one query; and about 90 % of all STs include five queries or less. The maximum number of queries in a single ST is 42; the second largest number of queries is 22. Queries are short: the median query length of 54 % of STs is one search key. STs with median of two-word queries are still quite common, about 27 %. The maximum median length of queries in an ST is 81, which is by far an outlier, since the second longest median query length is 17 keys. In order to smoothen the data, the outlier ST with 42 queries is from now on excluded from the analyses where the number of queries is discussed. Similarly, the ST with the median query length of 81 search keys will be excluded from the analyses concerning the median query length.

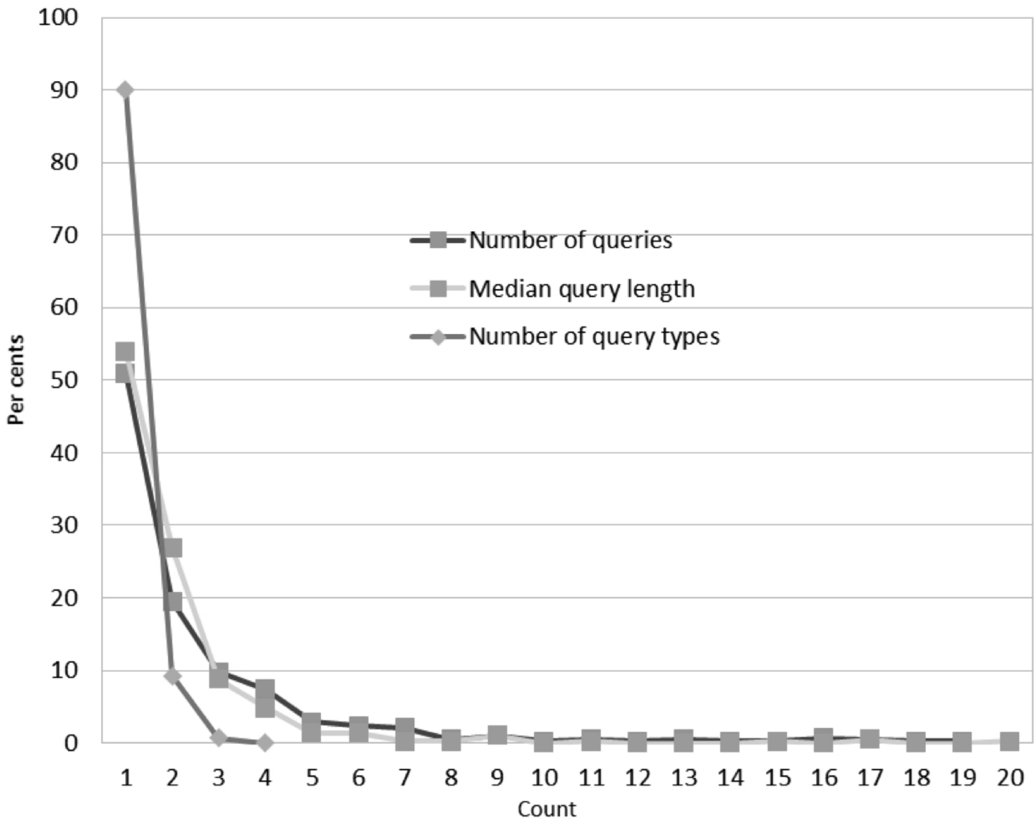

Figure 2. The distributions of number of queries, median query lengths, and number of different query types in STs (N=420). Note that the X-axis is cut and the maximum number of query types can be 4.

Query types p (proper names) and c (common nouns) are clearly most common. About 85 % of STs include queries of type p or c or both. Combinations of query types in STs are rare; this is again natural given the majority of short STs. Type p alone is the most common query type of ST, occurring in over half of STs. Below one fourth of STs are of type c.

Information retrieval in WTs of varying complexity

WT complexity's relationship to IR features is presented in Table 2, which gives the means and medians of IR features across WT complexity levels I-IV. Moreover, it shows the correlation coefficients and their statistical significance. WT complexity is connected to the *number of STs* (ϱ=0.16; p=0.006): the more complex the WTs, the more STs it includes. (See Table 2a.) The *number of queries* in an ST (see Table 2b) is weakly positively connected to WT complexity (ϱ=0.12; p=0.017). Mean and median show that the connection is curvilinear. However, studying the distributions more carefully shows that the longest STs (*i.e.,* with more than three queries) form 29 % of STs in the most complex WTs (category IV). Though one-query STs form over a half of the data, their share is smallest in the most complex tasks (IV), 42 %. Moreover, 45 % of the longest STs (with more than three queries) take place in the most complex WTs (IV).

Interestingly, the *median query length* is negatively albeit weakly connected to task complexity (ϱ=-0.12; p=0.016). Thus, the more complex the task, the shorter the queries (Table 2c). The drop in the mean seems quite small, but the difference is quite clear between the most simple and most complex WTs: data distribution reveals that though over one half of the queries have only one search key, the share of these short queries is largest (58 %) in the STs of the most complex WTs (IV), and the share of long-query STs (median query length of 3 or more search keys) is largest (24 %) in the most simple WTs (I). Perhaps it is easy to come up with search terms in simple WTs.

The number of different query types in an ST can vary between 1 and 4 but in our data the maximum was 3 (which forms only 0.7 % of the data). This aggregated variable correlates significantly with task complexity (ϱ=0.15; p=0.002). Table 2d shows that in the most complex WTs (IV), there are a little more query types on average than in simpler tasks (I-III). Actually, STs with two or three query types are clearly more common in the most complex WTs (IV) than in simpler ones (I-III), based on data distributions.

Table 2e shows the *frequencies of STs containing queries of each type*. The table is interpreted as follows: A query is of only one type, but an ST can include several queries and thus several different query types, respectively. The query type frequencies in Tables 2e, 3e and 4e are "dichotomic". For example, 35 STs of the total 59 STs (59 %) in simple (I) WTs include *p* queries; the rest, 24 STs (41 %) do not. The same applies to the other query types. The text includes a few calculation examples.

V-queries (predefined attribute value) are rare (found in only 23 STs). No linear trend is seen between task complexity categories despite the fact that the majority of *v*-query STs (78 %) ((7+11)/23)) happen in the more complex half of WTs (III-IV). *F*-queries (figures) share a similar pattern: 96 % of them happen in the more complex half.

C- and *p*-queries are more interesting because they are far more common. *C*-query STs pile up into the most complex WTs (IV): 43 % (54/127) of STs in complex WTs have *c*-queries and 39 % of all *c*-queries appear in the most complex tasks. *P*-queries differ from other query types. In all task complexity categories, STs including *p*-queries are more common than STs without them. However, the share of STs with *p*-queries is smallest (52 %) in the most complex tasks (IV).

Table 2a-e. The effects of WT complexity on STs and queries. Two figures missing an outlier are marked in **bold**. *Note that an ST can include several query types.

			Work task complexity				
			I	II	III	IV	total
a)	no. of search tasks in work tasks	mean	0.94	1.30	1.75	1.76	1.47
		median	0.00	1.00	1.00	1.00	1.00
		n	63	67	84	72	N 286
		rho; sig		ϱ=0.16; p=0.006			
b)	no. of queries in search tasks	mean	2.68	2.00	2.50	2.89	2.54
		median	2.00	1.00	1.00	2.00	1.00
		n	59	87	147	**126**	N 419
		rho; sig		ϱ=0.12; p=0.017			
c)	mdn query length of search tasks	mean	2.22	1.99	1.95	1.83	1.96
		median	2.00	1.00	1.00	1.00	1.00
		n	59	87	147	**126**	N 419
		rho; sig		ϱ=-0.12; p=0.016			
d)	no. of query types in search tasks	mean	1.07	1.06	1.09	1.18	1.11
		median	1.00	1.00	1.00	1.00	1.00
		n	59	87	147	127	N 420
		rho; sig		ϱ=0.15; p=0.002			
e)	freq of search tasks with each	*p*	35	66	91	66	258
		c	23	24	37	54	138
		f	0	2	25	19	46
		v	5	0	7	11	23

query type*	n	59	87	147	127	N 420

Information retrieval in different types of WTs

The relationships of IR features and WT types are presented in Table 3 which is similar in structure with Table 2. Note however that since WT types are qualitative features, calculating correlation was not possible. WT types' connections to the *number of STs* in WTs are shown in Table 3a. The average numbers of STs per WT in support, editing and intellectual tasks are 1.25, 1.43, and 1.65, respectively. Communication tasks have 1.43 STs per WT. Thus, intellectual tasks are most search-intensive WTs. Support tasks are interesting because they include the largest shares of both WTs with zero and with several STs. This means that typically, support tasks are performed with a lot of searching or entirely without it; intermediate forms are rare in this data set.

In all WT types, having only one-query STs is more common than having 2-3-query STs; which then is more common than having more than three queries in an ST. However, in intellectual tasks, having one, 2-3, or more queries is almost equally common, and the *mean number of queries* is higher than in other task types. It is notable that support tasks come close to intellectual tasks in the number of queries (Table 3b). STs in communication tasks tend to have the *shortest queries* (Table 3c). Again, support and intellectual tasks resemble each other in that they have longer queries in their STs. The sum of *various query types* (Table 3d) reveals that in support tasks and intellectual tasks, queries are more variable than in other types of WTs. The differences are small, however.

The occurrence of query types is again analysed as binary variables (Table 3e). The rare *v*-query searches happen almost exclusively in communication and support tasks (78 % in all, i.e., (8+10)/23)) whereas also the rare *f*-query searches take place in communication and intellectual tasks (87 %). *C*-query STs (as opposed to non-*c*-query STs) become more common in the continuum *support, editing, intellectual tasks* ranging from 25 % (14/55) to 44 %. *P*-query STs differ from other query types in the sense that in all WT types, it is more common that STs include *p*-queries than that they do not. This may partly be because proper names are highest in the hierarchy of query types, that is, a single proper name changes the type of the query despite any other search keys (see the explanation in the Analysis section). However, this is also a typical feature of the data: having proper names in most of the queries indicates quite specific information needs. *P*-query STs are least common in intellectual tasks (52 %). In communication tasks, *p*-queries are more common than in other task types. This is perhaps caused by extensive searching for people in email and instant messaging programmes, typical information sources in communication tasks.

Table 3a-e. The effects of WT type on STs and queries. Two figures missing an outlier are marked in **bold**. *Note that an ST can include several query types.

			Work task type				
			communication	support	editing	intellectual	total
a)	no. of search tasks in work tasks	mean	1.43	1.25	1.43	1.65	1.47
		median	1.00	0.00	1.00	1.00	1.00
		n	92	44	69	81	N 286
b)	no. of queries in search tasks	mean	2.05	2.59	2.12	3.30	2.54
		median	1.00	2.00	1.00	2.00	1.00
		n	132	**54**	99	134	N 419
c)	mdn query	mean	1.74	2.20	2.00	2.05	1.96
		median	1.00	2.00	1.00	2.00	1.00

	length of search tasks	n	132	55	99	**133**	N 419
d)	no. of query types in search tasks	mean	1.08	1.15	1.05	1.16	1.11
		median	1.00	1.00	1.00	1.00	1.00
		n	132	55	99	134	N 420
e)	freq of search tasks with each query type*	*p*	90	33	65	70	258
		c	28	14	37	59	138
		f	17	6	0	23	46
		v	8	10	2	3	23
		n	132	55	99	134	N 420

The effects of task complexity within task types

Next, the differences between searching in simple and complex WTs are discussed in the context of WT types. In order to study task type and task complexity's mutual effects on searching, we divided each task type into two categories; simple and complex tasks. Simple ones are former complexity categories I and II (complexity 0-38.3 %), and complex ones categories III and IV (38.4-100 %). As done in the previous sections, when suitable for the variables in question, correlations were calculated with the equidistant WT complexity measure. Results of the analyses are presented in Table 4.

Table 4a-e. WT complexity's effects on STs across WT types. Two figures missing an outlier are marked in **bold**. *Note that an ST can include several query types.

			Work task type								
			Communication		***Support***		***Editing***		***Intellectual***		
			simple	complex	simple	complex	simple	complex	simple	complex	total
a)	**no. of search tasks in work tasks**	mean	1.00	1.85	0.60	2.11	1.47	1.39	1.36	1.76	1.47
		median	0.00	1.00	0.00	2.00	1.00	1.00	1.00	1.00	1.00
		n	45	47	25	19	38	31	22	59	N 286
		rho; sig	ϱ=0.21; p=0.041		ϱ=0.41; p=0.006		ϱ=0.05; p=0.706		ϱ=0.07; p=0.53		
b)	**no. of queries in search tasks**	mean	2.02	2.07	2.40	2.67	1.88	2.44	3.33	3.29	2.54
		median	1.00	1.00	1.00	2.00	1.00	1.00	2.00	2.00	1.00
		n	45	87	15	**39**	56	43	30	104	N 419
		rho; sig	ϱ=0.08; p=0.372		ϱ=0.16; p=0.252		ϱ=0.05; p=0.605		ϱ=-0.03; p=0.749		
c)	**mdn query length of search tasks**	mean	1.96	1.63	2.07	2.25	2.36	1.53	1.77	2.13	1.96
		median	1.00	1.00	2.00	2.00	2.00	1.00	1.50	2.00	1.00
		n	45	87	15	40	56	43	30	**103**	N 419
		rho; sig	ϱ=-0.01; p=0.882		ϱ=-0.33; p=0.014		ϱ=-0.29; p=0.004		ϱ=-0.08; p=0.345		
d)	**no. of query types in search tasks**	mean	1.07	1.09	1.13	1.15	1.04	1.07	1.07	1.18	1.11
		median	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		n	45	87	15	40	56	43	30	104	N 420
		rho; sig	ϱ=0.07; p=0.412		ϱ=0.12; p=0.381		ϱ=0.06; p=0.587		ϱ=0.18; p=0.04		
e)	**freq of search tasks with each query type***	*p*	34	56	9	24	38	27	20	50	258
		c	10	18	5	9	20	17	12	47	138
		f	2	15	0	6	0	0	0	23	46
		v	2	6	3	7	0	2	0	3	23
		n	45	87	15	40	56	43	30	104	N 420

The number of STs seems to react differently to WT complexity depending on WT type (Table 4a). Firstly, the number of STs does not change with WT complexity in editing or in intellectual tasks.

In intellectual tasks, there is a slight increase in the mean which is not supported by the correlation. In communication tasks, the number of STs grows slightly with WT complexity. However, the number of STs is clearly connected to task complexity in support tasks (ϱ=0.41; p=0.006). While there was an overall tendency that WT complexity increases *the number of queries* in STs (Table 4b), the weak dependency vanished in the more elaborate type-wise analysis. Support and editing tasks seem to have an increase in the number of queries in STs between the two complexity categories though not supported by the correlations.

The median query length of STs requires careful analysis because the figures in Table 4c appear contradictory. The overall effect of WT complexity was, as seen earlier, to decrease query length. Editing tasks are the only WT type where this can be seen to be unequivocally true: the correlation is statistically highly significant (p=0.004), and satisfactorily high (ϱ=-0.29) considering the data. Also, both the mean and the median decrease. In communication tasks, the query lengths keep approximately at the same level. In support tasks, median query length is connected to WT complexity (ϱ=-0.33; p=0.014): the more complex the task, the shorter the queries. However, the mean seems to increase from 2.07 to 2.25, which must be caused by some outlier; the mean is sensitive to them.

In *intellectual tasks*, median query length seems to grow with task complexity. A closer review of the distributions shows that the growth is actually ambiguous. The distributions of STs between median query lengths of 1, 2, and more search keys are almost identical in simple and complex tasks. However, in simple WTs, exactly 50 % of STs have median query length of 1 key, whereas it is 49.5 % in the complex tasks. This causes the growth in the median. The mean is affected by the fact that the range of median query length is larger in STs of complex WTs; a few STs with long queries increase the mean in complex tasks. The correlation supports the interpretation that WT complexity does not affect the median query length of STs in intellectual WTs. Overall the median query length keeps at the same level independently of WT complexity, but when there are long queries, they tend to occur in complex intellectual tasks rather than in simple ones.

It is clear that queries become more diverse when task complexity increases only in intellectual tasks (ϱ=0.18; p=0.004). Otherwise, WT complexity does not affect *the number of query types*. Overall, *p* queries are the most common *query type* despite WT complexity or WT type. In editing tasks, WT complexity is not connected to the change of occurrence of any query types. In both communication and intellectual tasks, the proportion of STs with *p* queries decreases and with *f* queries increases. The proportion of *f* queries increases also in support tasks, whereas the proportion of *c* queries decreases in them. Each query type reaches its own peak as follows: *p* queries are most common in simple communication tasks (34/45=76 %), *c* and *f* queries in complex intellectual tasks, and *v* queries in simple support tasks.

Based on the frequencies of query types, it can be concluded that queries are typically quite specific. The fact that 'figure only' queries typically increase with task complexity is an interesting notion, since a figure is a precise search term. Perhaps the finding is related to the information systems used or the way they are used. STs with proper name queries become clearly less common only in communication and intellectual tasks. Especially interesting is that proper name queries, though overall common, are least common in the STs of complex intellectual WTs. On the other end of the continuum there are simple communication tasks, where proper names occur in almost 80 % of all STs.

Discussion

This study contributes to the knowledge of IR as a real-life phenomenon. The effects of WT type and complexity on IR features (the number of STs, queries, search keys, and the types of queries) were uncharted before. In this section, two main contributions of the paper are discussed: Firstly, the growing understanding of IR by using real-life data and how it affects designing future studies; and secondly, the empirical findings that show complex relations between WTs and IR.

Information retrieval as a real-life phenomenon

In the present study, the focus was, firstly, on carefully identifying WTs in the data. The second focus was on their subtasks containing IR, that is, STs. Other types of subtasks were left unanalysed. Some routine rules were first applied when defining an ST. As subtasks of WTs, STs cannot understandably cross the boundaries of WTs.; and neither can overlap each other. This was partly a pragmatic decision, partly because an information need is a fluctuating state of mind (*cf.* Belkin's (1980) model of Anomalous States of Knowledge); if one IR session ends and another begins, it seems unlikely that a person would later return to and continue from exactly the same information need (”state of knowledge”). Here the information need or the ST is not a written description handed to the participant but rather a self-created and implicit phrasing of a question or a state of mind. This corresponds to the ‘internal generated’ value of ‘source of task’ facet in Li and Belkin’s (2008) comprehensive task classification.

This view of non-overlapping STs differs from Spink and colleagues’ (2002) view on the popularity of multitasking. Their view is based on overlapping of abstract *topics* that were of recurring interest for the searchers. However, our interpretation of information needs is based on the fact that they were created *ad hoc* by the participants and immediately led to concrete steps of IR, the ST. Such quick, time-bound episodes of arising information needs and instant searching are not so likely to overlap.

The findings of the study supported the view that IR is one of many means to achieve a goal, the task outcome (Ingwersen and Järvelin, 2005; Järvelin *et al.*, 2015; Rose and Levinson, 2004; Wildemuth and Freund, 2009). This is seldom explicitly taken into account empirically. Assigned STs in test settings keep static. However in authentic WTs, both the physical retrieval actions and the mental model of the task performer are all the time in a complex interaction with all the possible contexts (cf. the shifts in intentions and information seeking strategies analysed by Xie (2000)). This is in line with the acknowledged difficulty of defining context conceptually (see e.g. Courtright, 2007; Dervin, 1997). Thus calling the authentic phenomenon information searching instead of IR seems more appropriate; people are trying to find information rather than simply retrieving it.

A typical ST in the data was in a common WT, ‘replying/reacting to emails’. The emails received need not include extensive requests for information but even small questions and situational notices from a supplier may lead to further information needs and searching beyond the obvious matters presented in the email. Finding information to reply emails could last most of the working day leaving little time to the so-called core of work.

Another example of information-intensive but not IR-driven WT is a situation where a manager has a task related to a decision to update the design of a product. She does not design by herself but coordinates it. During the observation, she tried to gather together the best experts within the organisation. Mostly she knows them by heart, but sometimes email addresses have to be checked. This is quite trivial. However, she suddenly has the suspicion that one of the experts has been replaced by another one she does not yet know. Because she is not sure, she tries to find the information from the intranet. That being unsuccessful, she has to call to two colleagues, which requires identifying the right people and finding their contact information.

Afterwards, one can say that in the above situation, there was an ST of finding that missing expert, and the participant herself might have been able to tell beforehand, if asked in enough detail, that she has to find the relevant experts. However, the problem (the uncertainty) was unlikely to be known beforehand, and the situation led to a small-scale but important IR in view of the larger task she was responsible for, the successful design of a product. The participant was also able to choose – at least in theory – between several options how to proceed with the task.

Since IR is a natural and inseparable phase in the flow of WTs, it is difficult to integrate into simulated WTs. In the present study, the data had only two WTs where the participant explicitly stated that the WT goal was to find information. STs did not exist as systematically designed assignments in the minds of the participants but they were normally really spontaneous and thus quickly evolving. Though definitely an important part of many tasks, IR was surprisingly rare; there were STs in only 60 % of all WTs. STs were simple: half of them had only one query. This seems to be connected with the role of IR in WT performance. It may be crucial but the WT is not in itself an ST, the ruling type of simulated WTs where IR is something the participants are expected to do, despite the background story.

The role of IR in real life sets new questions on how to assess search performance. The relevance of documents or some other measure of success is often of interest in traditional IR studies and even in naturalistic IIR studies (Kelly, 2006). Measuring success was intentionally left out from the present study because other study interests seemed more relevant in the context of real life. As already emphasised in this paper, STs were intertwined into other work activities; STs and information needs arouse and ended naturally. There were no official assignments whose information requirements could be compared to the output or outcome of IR. The main issue was to proceed in the WT and continuously select suitable paths to pursue. Successful IR at least sped up the task process but a failing query simply had to be managed somehow. Abandoning a WT was not an option. Since information needs also evolve it would have been quite hard to evaluate success as an outsider or even to cut the STs into components to be evaluated. Should this have been done after each query? What about exploratory searching?

Empirical findings

In this study, IR was studied without stimulating it; *i.e.*, simply by observing WTs and noting when an ST occurs. It was found that not all WTs include IR. In the WTs that did, it seemed quite simple. The STs were short in the number of queries, as well as the queries in the number of search keys. The prevalence of short queries is shown in many earlier studies (Silvestri, 2010); people do not search more than they have to. Jansen and Spink (2006) show the prevalence of single-query search sessions: on average, they comprise about a half of all sessions. This is surprisingly similar to our finding though our ”sessions” were not technically but content-wise limited STs and included also other sources besides the web. Overall, queries were quite specific because most STs featured queries with proper names. This finding is in line with those of Huurnink and colleagues (2010). Spink and colleagues (2004) found that in web search engines, queries with personal names (a subset of proper names) are quite common. Of course, personal names in web searching differ from the multi-source, work-related searching in the present study: Spink and colleagues (2004) found that most personal names searched for were names of celebrities whereas in our study, a typical person name query was for finding contact information.

Growing task complexity slightly increases the number of queries in STs and the number of STs in WTs. This could be expected since the more complex the task is, the more new information is needed. These findings are in agreement with Saastamoinen and colleagues (2012) and Aula and colleagues (2010). However, the correlations found here are so weak that several other factors must affect the number of STs and queries along WT complexity. High WT complexity may indicate that the WT is formed of several subtasks with different information needs, but fulfilling these information needs does not self-evidently lead to clearly increased IR. This is because task performers have several options to proceed: issuing a query in an information system is seldom precisely planned beforehand but only performed ‘ex tempore’ if considered the optimal way to go.

Based on the correlation coefficient, queries tend to become shorter when task complexity increases. It may imply that the information needs behind queries become more unspecific (cf. Vakkari, 2001). This interpretation is supported by the fact that the share of STs with proper name queries is smallest in the most complex tasks. The connections between shorter queries and more complex tasks has been referred to in, e.g., Liu, Kim and Creel (2015), Hansen (2011) and Vakkari (2001). Vakkari’s findings also show that the more complex the task, the more vague are the search terms used. Aula and colleagues (2010) defined difficult STs as unsuccessful and easy as successful. Their findings show, contrary to the ones presented here, that the difficulty slightly increases the number of query terms per query. The difference can be caused by many factors: a complex WT does not necessarily imply complex STs (Aula *et al*. (2010) considered only STs). Also the methods and operationalisation of complexity were different.

Exploratory versus lookup STs are discussed by, *e.g*., Marchionini (2006), White and Marchionini (2007), and Wildemuth and Freund (2012; 2009). To some extent, explorative searches can be considered complex and lookup searches simple; and by definition exploratory STs should include more searching (White and Marchionini, 2007). However, a complex WT does not determine that the STs are complex. Exploratory searching is often defined by multiple factors (Wildemuth and Freund, 2009). The definitions seem not to differentiate between complex information needs and complex search actions which may not coincide. A factual, "simple", information need may end up in complex search actions, and on the other hand, a larger, topical information need may be quickly fulfilled. The earlier findings based on the same data set (Saastamoinen and Järvelin, in press) show that even in the complex, and in the intellectual tasks, most information needs and search processes are simple. However, topical needs and developing search processes are more common in the most complex and in the intellectual tasks than in other task types or complexity categories (Saastamoinen and Järvelin, in press).

WT types brought an interesting perspective and a contrast to task complexity. To some extent, support, editing and intellectual tasks formed a continuum equivalent to task complexity. Common nouns as query types in STs became more common along this continuum which may imply the information needs becoming vaguer (cf. the paragraph above). In intellectual WTs, the STs featured more queries than in other task types. This resembles the findings of the connections between WT complexity and STs.

It seems that task complexity's effects on IR are best elicited within task types. In *support tasks*, correlations clearly show that WT complexity increases the number of STs and shortens the queries. Thus WT complexity is actually an important factor affecting IR in support tasks, though they can easily be neglected in IR research as uninteresting routine. Typical assigned STs or simulated WTs often require searching information about something rather unfamiliar to the participant in order to compile some sort of aggregate of the information found. Still, these kinds of tasks seem rare in the flow of work and they would also represent quite complex tasks. Support tasks – if found complex – are often experienced especially frustrating because the task performers, too, anticipate that they are routine. It is interesting, that in *editing tasks*, simple WTs include more STs than complex ones. However, at the same time the share of STs with several queries increases clearly and queries become shorter with growing WT complexity.

Intellectual tasks are the opposite of support tasks: task complexity does not affect almost at all the number of STs or the query length. This indicates that searching is built-in in tasks where something new is created. However, the types of queries change and become more variable: task complexity does not affect the quantity of searching but its quality.

Communication tasks are special because they are common but varying in their content. Nearly a third of WTs belong to this category which is similar to the findings of Czerwinski, Horvitz and Wilhite (2004). Communication tasks are important, though they actually often only support other tasks. When communication tasks become more complex, the number of STs increases and queries change. With growing task complexity, searching with people's names and other proper names decreases and using figures increases. This finding may originate especially from communication tasks in commercial companies. Figures are really specific search keys (such as product codes) that worked as starting points when the participants were trying to solve complex inquiries received through email, for example. Thus seemingly specific search keys worked in the context of more muddled information needs.

Conclusions

This study provided an in-depth view on authentic IR. IR is seldom studied with its natural context that is underlying WTs. The main contributions include the following:

The basic principle through all data collection and analysis phases was to stay true to the authentic phenomena of IR. It means reconsidering many preconceptions and prevailing practices. One of the main points was that the researcher identified the endogenous, spontaneous STs rather than setting an experiment. IR is an integral part of the flow of WTs. People do not normally start working search-minded. It may be that STs could be afterwards clearly identified by researchers or even by the participants themselves; but IR is seldom a part of a work plan. Without a doubt, this is a feature dependent on work role, profession and task. However, the search actions in the present data were mainly quick (often nearly inadvertent) choices made between, for example, browsing, calling a colleague, looking up in a book, delegating, *etc*. *Why* IR was selected among the alternatives would be an interesting research question

To maintain validity of IR experiments, attempts should be made to retain the work flow context in the more controlled experimental environments. It would be important to study whether the claim that simulated WT situations are actually rare in practice also holds for other settings than the ones analysed here. The present findings can be exploited when designing simulated WTs that would better correspond to authentic WTs. The scope of IR studies should exceed search intensive tasks and include also tasks where IR is brief while still important. Otherwise the development and evaluation of IR methods are not based on the whole range, or even the common types, of STs. In reality, a single ST may be straightforward, but together all STs form a versatile whole, considering, for instance the information resources. In a typical (I)IR experiment, a major deficiency is that the participants cannot choose where to search.

The findings suggest that simulated WTs could be more problem-driven rather than directly stating to the participant that the idea is to find certain kinds of documents, which is an unusual type of WT in the present data. This would require more tailoring of the simulated WTs. The participants should be directed in a situation where they decide to search rather than letting them read the ready-made information (or document) need. An option would be to ask the participant first to do something that is not actually in focus, but that leads to some sort of ‘problematic situation’ where she has to find further information to proceed in the initial task. This problem solving stage would represent a naturally formed ST, the key interest for the researchers.

A data-driven classification for WT types was formed. It proved useful in providing further insight into IR actions. The WT types do not depend on organisation type but represent abstract features of tasks. They might serve as a starting point when classifying tasks or designing simulated WTs in later studies. The task type classification seems applicable to other organisational settings beyond the ones studied. However, its applicability may depend on how information about the WTs is collected. In the present paper, participants’ free-form, written task descriptions were used. The WTs may appear differently if described by the researchers. Since this was the first time this classification was applied, it may need revisions in the future. Perhaps some work roles include several WTs that build around information seeking, which then could be an additional category.

The authors’ opinion is that naturalistic IR studies should be regularly conducted to ensure the relevance of state-of-the-art IR experiments for the end-users and authentic use situations. An interesting future study object could be information workers in small companies. Typically, their work is really variable (compared to large companies where the work roles are potentially more differentiated), and they may not have expensive and advanced information systems and databases in use. This kind of environment places high demands on the available systems and their ways of use.

It would be optimal to conduct naturalistic studies in a larger research group to increase the number of participants without losing the quality, the depth of the study. With a larger data set, a more thorough statistical analysis would be possible. This would foster theory growth in the field. The present study is exploratory, but in the future, even naturalistic studies can be more clearly focused without having to artificially control the participants. For these purposes, the paper presented easily applicable operational definitions of WTs, STs and their features. Instead of focusing on the development and evaluation of individual information systems, it is time to find out how people act in their information environments, what the role of various information systems is in their activities, and when, why and how they ask questions to be answered by which systems.

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Appendices:

Morning questionnaire

What WTs do you have to perform today? Base your replies on your present knowledge.

<u>Contact information</u>

Name:

Organisation:

<u>Tasks</u>

[The questionnaire includes place holders for 5 tasks. Each slot is of size one line and approx. 40 characters but allowing the participants to type more. The participants fill in as many tasks as they need to. For each:]

The WTs of today. Task complexity should be given as a number 0 (really simple)-100 (really complex).

Task description:

Task complexity 0%-100%:

Task performance. You should answer with a number 0 (not at all)-100 (perfectly) to the question of how well you know the task performance process.

Programs/information systems needed:

Other information/sources of information needed:

How well do you know the task performance process?:

Other remarks (e.g. about the tasks or the course of the day):

Afternoon questionnaire

What WTs did you perform today? Think about the whole working day from the morning to the afternoon as you reply.

<u>Contact information</u>

Name:

Organisation:

<u>Tasks</u>

The WTs of today. Task complexity should be given as a number 0 (really simple)-100 (really complex).

[The questionnaire includes place holders for 5 tasks. The participants fill in as many tasks as they need to. For each:]

Task description:

Task complexity 0%-100%:

At what time (approximately) did you perform the task? (E.g. 12-13)

Task performance

Programs/information systems you used:

Other information/sources of information you used:

Did any problems turn up in the task? Please describe them.

[The questionnaire includes places for 5 tasks; the participants fill in as many as they need to.]

Other remarks (e.g. about the tasks or the course of the day):

Saastamoinen, M. & Järvelin, K. Relationships between work task types, complexity and dwell time of information resources. Journal of Information Science. [In press.]