

Semantically Enriched Information Seeking in Peer-to-Peer File Sharing Systems – Empirical Evidence from the User Perspective

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Abstract

In Peer-to-Peer (P2P) based file sharing systems, keyword-based retrieving is the predominant search functionality. Both, the emergence of semantic web structures and research results on user behavior indicate that in certain circumstances, browsing in semantic networks is not only the more efficient search functionality in specific cases, but also leads to a higher user satisfaction.

In this paper, our research objective is threefold. First, we want to explore currently provided search mechanisms in P2P file sharing systems in order to uncover a possible lack in the provision of user-friendly search functionalities. Second, we want to examine for P2P file sharing systems whether information browsing on semantic networks and keyword-based searching lead to significant differences in search efficiency and user satisfaction. Third and closely related to the second research aim, we want to additionally investigate the predictors of search efficiency, user satisfaction and usage intention in the context of P2P file sharing systems.

1. Introduction

Recent evolutions in the Internet point to a more semantically organized structure, a fact that might also deliver some suggestions for P2P systems. In an exploratory study we found that although inside most file sharing systems keyword search is the predominant search functionality, users do also face search situations that might be better matched with browsing functionalities like hyperlink topologies. In most cases, however, browsing structures are not provided inside P2P file sharing systems, but in externally associated Internet forums. This may indicate a perceived lack of semantics inside P2P systems. Addressing this assumption, in this paper we want to transfer the well known hypertext-based browsing vs. searching discussion to the P2P research field. As P2P file sharing systems are based on a completely different data management concept than Client/Server-based Internet systems, a simple transfer of the empirical results from Hypertext to P2P research might be insufficient. Our aim is to examine if employing network-based browsing functionalities compared to keyword-based search functionalities in P2P systems can

enhance both search efficiency and user satisfaction in specific search settings.

After outlining the state-of-the-art in semantically enriched P2P file sharing systems and user search behavior literature (chapter 2), we present a multi-method research design we applied to observe 80 participants interacting with keyword-based searching and network-based browsing functionalities on a simulated P2P environment (chapter 3). In chapter 4, we present selected findings of the exploration and lab experiment phase of our research study and its implications on the design of future P2P file sharing systems. Finally, the article concludes with the limitations of our study as well as with potentials for further research (chapter 5).

2. Related work

In the following, we present related work on technological trends in the field of organizing information in P2P-based systems on one side and research results of users' search behavior and technology acceptance on the other side.

File sharing systems are one of four Internet applications based on P2P technologies and allow a decentralized exchange of files [1, 2]. These systems have recently emerged at a high speed, leading to a broad discussion on this topic and its consequences in different research areas [3, 4]. With respect to the organization of decentrally held information in a way that relevant information can easily be found, P2P research takes up the discussion of the Internet's evolution towards a semantic web [5, 6].

Schlosser et al. [7] present a system called HyperCuP in which semantically related Peer-to-Peer nodes are connected to one so-called hypercube according to the predominant type of content offered. Each hypercube represents one ontology concept so that a search for a certain keyword leads the user to a group of nodes with a high probability to find relevant pieces of information.

The work presented by Crespo and Garcia-Molina [8] approaches the issue of organizing peers logically from a different point of view. Peers can be part of several so-called Semantic Overlay Networks (SONs) depending on the classification of their content. The question here is how many SONs one peer should join. If one peer joins a rather big number of networks, search precision might be low, in other words too many results are listed which do

not exactly correspond to the user's information needs. On the other hand, if each node is only part of very few SONs, search recall may be low as some relevant data might not be found with a certain keyword.

Nejdl et al. [9] center on the question of standardization and set up the idea of a super-peer network which draws on the RDF (Resource Description Framework) standard. While the examples discussed before concentrate on building up a different logic on Peer-to-Peer structures, Nejdl et al. take a heterogeneous environment of different Peer-to-Peer systems as a given fact. They concentrate on the conception of metadata services that enable interoperability between as well as scalability of different file sharing systems.

Figure 1 depicts different P2P research fields from a layer perspective. The user interface layer falls back on the underlying semantic structure which in turn is modeled according to the organization of distributed data.

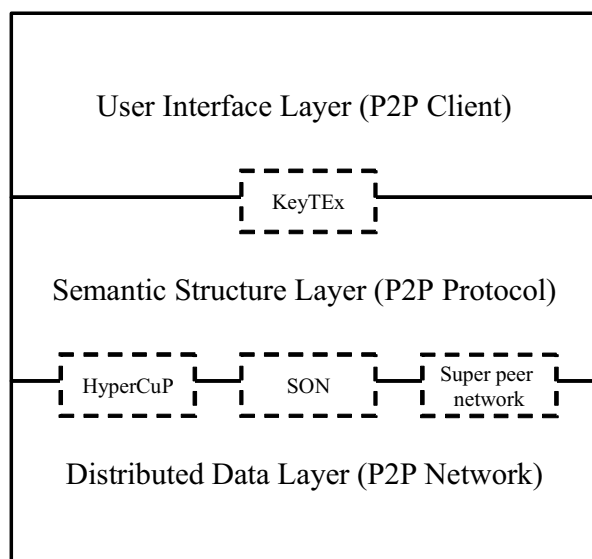


Figure 1. Research upon a semantic organization of Peer-to-Peer networks on different layers

The concepts of super-peer networks, SONs and HyperCuP link the provision of a semantic structure with the distributed data layer. They discuss interoperability and semantic data as two of the focal points in this field [10] as well as efficiency in the context of algorithm performance and resulting network load. Our approach is “set on top” of this work as it provides a concrete user interface (KeyTEx¹, see [11]) for a given semantic structure. In detail, we assume metadata to be assigned to files and the organization of metadata in appropriate ontologies. We explicitly do not go into the issue of interoperability, while centering on the users’ perception of semantic data in file sharing networks. When talking

about “efficiency”, we take system efficiency for granted and focus on concrete search efficiency from the user information behavior perspective.

In information behavior research, predominantly discussed in the research field of information studies, human information behavior is described as a cycle of information needs, seeking and use activities [12, 13]. In this paper we focus on the seeking part of the cycle which can be further subdivided. Classifications of terms like exploring, searching, browsing or retrieving are manifold and ambiguous [13, 14]. In the article at hand, we follow Shneiderman [15] who simply decomposes the task of fact finding in searching and browsing. In our definition, searching will equal keyword-search while browsing refers to an indirect clicking-mode through logically structured data. Browsing can be further subdivided into hierarchical browsing (e.g. Windows Explorer) and network-based browsing (e.g. KeyTEx) with the latter being investigated in this study. Research on the comparison between searching and browsing has shown that browsing on semantically enriched index structures is advantageous to keyword-based searching in those search settings where the user seeks information in a rather unfocused way (e.g. doing research about a certain topic domain) or searches for a collection of highly-interrelated pieces of information (e.g. documents) [16, 17]. Additionally, for the concrete example of electronic databases and hypertext information environments like the WWW [14, 16, 18], researchers in information behavior could show that browsing can be more efficient than searching, contingent upon the domain expertise and the specificity of the search task. Both search functionalities should therefore complement each other and be integrated together on top of knowledge domains, as can be seen in Internet search engines.

Indeed, in other research results, browsing and searching are rather seen as complements than as substitutes [19]. The rationale behind integrating both search techniques in one user interface is presumed to be that each of both search mechanisms provides advantages for different search settings. Relevant independent variables in this context are prior knowledge, the level of specificity or tangibility of the search goal of the user (broad or narrow; one or multiple search items, etc.), the search tool type and the complexity of the searched piece of information (one central or a multitude of identifying attributes) [16, 20-22]. This rather technical view on the *efficiency* of user search behavior is, however, only one side of the coin, as a number of researchers have pointed out in their studies [23, 24].

The other side is users’ attitude towards and acceptance of technologies. While the constructs of acceptance and attitude have been discussed much earlier [25], a standard approach in the technological context is the so-called Technology Acceptance Model [26]. Research studies suggest that user satisfaction is one of

¹ Keyphrase Extractor and Topic map Explorer

the key factors to IS success [27] measured by the intention to use the respective IS. User satisfaction itself is influenced by a multitude of factors like for example the perceived usefulness or the perceived ease-of-use [26].

Drawing on the results of previous studies in technology acceptance modelling, we want to investigate a meta-level research question in a first step. We are interested in the extent to which the underlying search functionality and the specificity of the search task influence search efficiency and user satisfaction in P2P-based search environments. Additionally, we want to explore whether search efficiency and user satisfaction are significant predictors of the intention to use P2P file sharing systems.

Transferring the experimental research design of previous information behavior studies to the P2P research area as a second step, we assume that due to the decentralized nature of P2P-based file sharing systems, user interfaces that provide network-based browsing functionalities inside P2P file sharing applications can optimize searching behavior (efficiency) and especially user satisfaction contingent upon the specificity of the search task the user has to fulfill.

Consequently, we try to integrate both the search efficiency and the user satisfaction perspective into the following hypotheses:

Hypothesis H1)

In focused search tasks in P2P-based file sharing systems, searching with a keyword-based search functionality

- a) is more efficient
- b) contributes to a higher user satisfaction than browsing in a semantic network.

Hypothesis H2)

In unfocused search tasks in P2P-based file sharing systems, browsing in a semantic network

- a) is more efficient
- b) contributes to a higher user satisfaction than searching with a keyword-based search functionality.

3. Methodology

With the aim to motivate our research and to test our hypotheses and research question, we employed both an exploratory investigation of search functionalities in Peer-to-Peer networks and an according lab experiment. Before we present the experimental design of our research study in section 3.2, we briefly outline the method we applied in the exploratory analysis.

3.1. Exploratory analysis

In order to evaluate browsing mechanisms provided by P2P-based file sharing clients (internally) or externally

associated Internet websites², a categorization scheme was developed (see Table 1).

#	Browsing category	Explanation
1	No associated browsing	Neither internal nor external browsing functionalities (links, higher-level topologies)
2	Simple internal browsing	e.g. flat, not structured links to promoted files within P2P system
3	Simple external browsing	e.g. flat, not structured links within external Internet forum that start the download in P2P systems
4	Enhanced internal browsing	Internal link topologies from abstract to more concrete concepts of the search domain
5	Enhanced external browsing	External link topologies from abstract to more concrete concepts of the search domain

Table 1. Coding scheme for exploratory analysis

Based on the categorization scheme, 14 of the most utilized P2P clients (e.g. KaZaA, eDonkey, iMesh, etc.) were evaluated and classified (see section 4.1).

3.2. Lab experiment

In order to investigate the hypotheses developed in chapter 2, we used a 2x2 factorial design. We combined the values of the independent variables *specificity of search task* and *search functionality* resulting in four different cells (see Table 2). In each of the four cells, the dependent variables *search efficiency* and *user satisfaction* should be assessed [28]. Each participant was randomly assigned to *only one* cell resulting in four experimental groups.

Search task spec. Search fct.	Focused	Unfocused
Keyword-based search	Group I Search efficiency User satisfaction	Group III Search efficiency User satisfaction
Network-based browsing	Group II Search efficiency User satisfaction	Group IV Search efficiency User satisfaction

Table 2. 2x2 factorial design

The 2x2 factorial design led to the following structure for the experimental setting:

- In a pre-experimental questionnaire we investigated basic socio-demographic, PC, Internet and P2P usage data. As a guideline, items of similar studies were selected [29, 30].

² e.g. <http://www.overnetworld.com>, <http://www.dsom.com>

- A lab experiment where we observed the search behavior of the experimental participants allowed us to collect data on *search efficiency*.
- A post-experimental questionnaire provided information about *user satisfaction* via perceptual data.

Before we describe our research variables, the participants and procedures in the subsequent sections of chapter 3, we now shortly introduce the search domain we employed for the experimental setting. As we assume an evolution towards an ever-growing representation of complex and heterogeneous data in P2P file sharing systems, we chose a rather complex seeking domain compared to common music or video file sharing systems. In detail, we employed the domain of scientific research activities (including authors, researchers, research topics, publications) at the Institute of Information Systems and New Media (ISNM, University of Munich) as exclusive source of data. A fixed set of publication documents formed the basis for all groups of the experimental design.

3.2.1. Independent variables. The variable “specificity of search task” has two values, focused and unfocused. The tasks were presented to the participants in the form of two focused or two unfocused search questions according to the test group they were randomly assigned to (see Table 2). Both the focused and unfocused search questions varied in the degree of specificity and were designed as follows:

Focused search tasks:

1. Find a known-item article by its known title.
2. Exhaust all articles on a given subject (unknown articles).

Unfocused search tasks:

3. Find two journals in which there are publications by researchers at ISNM (journals and publications unknown).
4. Find all authors at ISNM who ever published (authors unknown).

The values of the second independent variable “search functionality” are “keyword-based search” or “network-based browsing”. For the case of keyword-based searching, the participants had to use the search engine that comes along with MS Windows Explorer. In order to effectively simulate the prevalent Peer-to-Peer search environment, we arranged the test design in a P2P typical manner. First, we allowed the participants only to fill in the search field for titles of files and directories. Second, the search was limited to a flat structure of six exemplary peer folders, all located in the same directory. Third, the files to be searched were redundantly spread over the folders and annotated with metadata information.

For network-based browsing, we employed the ontology-based tool called KeyTeX, which was developed based on the open-source project TM4J (www.tm4j.org) at the ISNM. KeyTeX allows browsing in a spider web-

like network of topics depicted in Figure 2. Peers and additional semantic meta-concepts of the knowledge domain were modeled as hyperlink nodes. Relationships between nodes represented associations, aggregations (compositions) and inheritances. Although the topic map was based on the same logical set of semantic information compared to the folder concept mentioned above, most important difference of KeyTeX was explicitly the higher-order and thus semantically enriched abstraction from the physical content. Although KeyTeX encompasses a complementary index list with all concepts within the knowledge domain (to be seen in the left column of Figure 2), this functionality was explicitly removed during the experiment with the objective of simulating a pure network-based browsing situation.

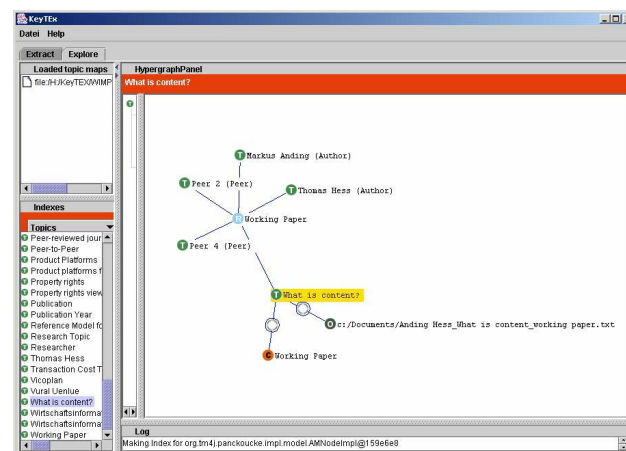


Figure 2. KeyTeX tool for network-based browsing

KeyTeX relies on the concept of XML-based topic maps (XTM) which have evolved out of the research activities on XML and the HyTime Topic Maps of the ISO 13250 standard [31]. Topic maps have been established as an answer to the problem of organizing semantic interrelationships between information units in large knowledge bases. Primarily, the topic map standard was established to handle the construction of indexes, glossaries, thesauri and tables of contents, but its applicability extends beyond that domain. As topic maps generally lay out a structured metadata vocabulary that point to separately stored information resources, topic maps also appear to be a promising standard for network-based information retrieval [32].

Figure 3 shows a small fraction of the topic map used to model the knowledge domain (i.e. ontology) for the experiment. Among other things, one can see topics (research fields, authors, peers, etc.) and concrete occurrences (in our case research documents) as well as associations building up connections between different topics and between topics and occurrences.

```

<?xml version="1.0"?>
<topicMap xml:base="http://www.wi.bwl.uni-muenchen.de/default.xtm"
  xmlns="http://www.topicmaps.org/xtm/1.0/"
  xmlns:xlink="http://www.w3.org/1999/xlink">
  ...
  <topic id="00021">
    <instanceOf>
      <topicRef xlink:href="#00001"/>
    </instanceOf>
    <baseName>
      <baseNameString>Working Paper</baseNameString>
    </baseName>
  </topic>
  ...
  <topic id="00043">
    <instanceOf>
      <topicRef xlink:href="#00021"/>
    </instanceOf>
    <occurrence id="id004">
      <resourceRef xlink:href="c:/Documents/Anding Hess_What is content?"/>
    </occurrence>
    <baseName>
      <baseNameString>What is content?</baseNameString>
    </baseName>
  </topic>
  ...
  <topic id="00102">
    <baseName>
      <baseNameString>Peer</baseNameString>
    </baseName>
  </topic>
  ...
  <topic id="00202">
    <instanceOf>
      <topicRef xlink:href="#00102"/>
    </instanceOf>
    <baseName>
      <baseNameString>Peer 2</baseNameString>
    </baseName>
  </topic>
  ...
  <association id="Peer2ToWhatIsContent">
    <member>
      <roleSpec>
        <topicRef xlink:href="#00102"/>
      </roleSpec>
      <topicRef xlink:href="#00202"/>
    </member>
    <member>
      <roleSpec>
        <topicRef xlink:href="#00021"/>
      </roleSpec>
      <topicRef xlink:href="#00043"/>
    </member>
  </association>
</topicMap>
    
```

Figure 3. Topic Map of ISNM publications with P2P-related nodes

3.2.2 Dependent variables. In the following, we discuss the experiment's two dependent variables, "search efficiency" and "user satisfaction". According to the 3 layer perspective we introduced in chapter 2, these variables address the intersection of the user interface layer and the semantic structure layer as can be seen in Figure 4.

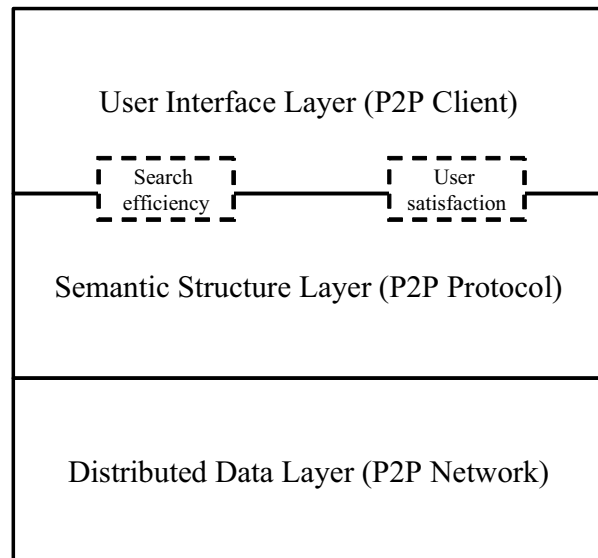


Figure 4. Dependent variables from the layer perspective

The two variables were measured with different instruments. Data concerning "search efficiency" was generated by observation of the computer-based search test. Each candidate's search behaviour was accurately recorded with the screenshot capture software HyperCam³. The experimental setting allowed a simple fulfillment of all search tasks so that measuring recall and precision as it is found in typical retrieval studies was not necessary. Accordingly, search efficiency was measured by the time users needed to fulfill the given search tasks.

As the "user satisfaction" has been a significant predictor of the attitude towards using and accepting a system in previous acceptance studies, we chose it as the second central dependent variable (see chapter 2). It was measured by the post-experimental questionnaire. After having screened a list of potential standardized measurement instruments devised to systematically capture aspects of usability respectively acceptance criteria, the Post-Study-Satisfaction-User-Questionnaire (PSSUQ, [33]) was chosen, slightly adapted to a non-technical wording and extended by typical aspects relevant for search systems (resulting in 20 statements in total measuring the constructs *perceived ease of use*, *perceived usefulness*, *simplicity*, *ease of learning*, *effectiveness*, *systems capabilities*, *user interface design*, *user satisfaction* and *usage intention*).

Before collecting data for the experiment, reliability of the measures was determined. The coefficient alpha analysis of the PSSUQ showed that the reliability of the questionnaire was 0.97. As we added additional items to account for the special search scenario, we executed an

³ <http://www.hypercam.com>

additional reliability analysis after having collected the data. With an average reliability coefficient of $\alpha=0.94$, the items still showed a high overall reliability. The validity of the questionnaire was indicated by the high correlation between the questionnaire score and the percentage of successful scenario completions in usability tests [33].

3.2.3. Participants. 90 undergraduate and graduate students with a major in Information Systems and New Media Management (mean age = 23.7 years, SD = 2.8 years) at the University of Munich were recruited as participants in the experiment. Although the sample cannot be viewed as a “representative” cross-section of P2P users, students have specifically been identified as heavy users of P2P networks and thus account for a considerable part of the P2P user community. After the execution of the lab experiment we had to eliminate 10 cases because of missing values in the dependent variables (i.e. missing PSSUQ values and flawed screenshot captures). Missing values of the independent variables (i.e. missing values in pre-experimental questionnaire) were replaced with the value of the arithmetic mean. Therefore, we base our analysis on 80 cases with 20 cases randomly assigned to each group in our experimental design.

The pre-experimental questionnaire indicated that all participants were relatively experienced computer and Internet users. On average, a participant had used a computer for more than 5 years and Internet for 3-5 years (on average 1-3 hours a day). 75% percent of the participants were active P2P users, using P2P systems on average for 1-3 years, about 8 days per month and less than one hour on an average day.

To provide for the comparability (variance homogeneity) of the characteristics of the randomly assigned participants to the four cells of the experimental design, both the PC, Internet and P2P experience were controlled among the different experimental groups. We also controlled the prior acquaintance of the test persons with the ISNM domain which was comparatively low on average.

3.2.4. Procedures. All participants were randomly assigned to one of the experimental groups, in other words to a certain combination of “search functionality” and “search task”. At first, all participants were presented an identical pre-experimental questionnaire. Before starting the actual experiment, the candidates were briefly instructed and trained with the seeking method they were to use in the experiment in order to level out familiarization effects. Following, the users were given the two questions either on the focused or the unfocused search task. After finishing each search question, each candidate was requested to note the answers. Finally all

participants had to fill in an identical post-experimental questionnaire.

4. Results and discussion

Before going into the findings of the experimental design in 4.2, descriptive results of the exploratory analysis are presented in the following section.

4.1. Exploratory analysis

In our exploratory analysis, we discovered that most of the evaluated P2P systems don’t offer any browsing functionality. Those P2P systems that offer some sort of browsing mechanism most often do so in the form of associated Internet forums linking to P2P resources. Only a fraction of the evaluated P2P systems provided simple browsing capabilities within the P2P application itself (see Figure 5). Equally astonishing was the fact that both within P2P applications and in externally associated Internet forums, higher-level browsing topologies (e.g. link hierarchies or networks) that are well-known from Internet search engines⁴ were lacking.

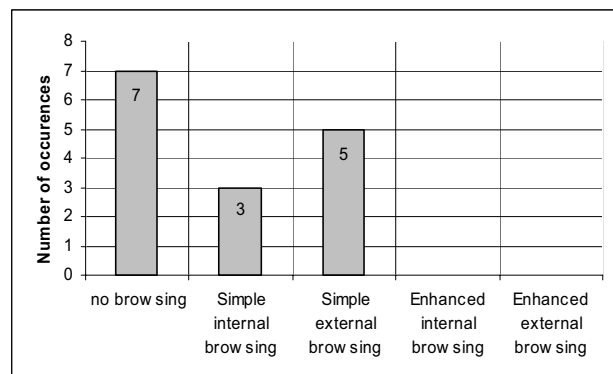


Figure 5. Supported browsing mechanisms in P2P Systems

These results give rise to the question why higher-level browsing functionalities are not provided within P2P-based file sharing systems. Does it depend on lacking technical feasibility or is there no need from the user’s perspective? These questions lead us to investigate these issues from a combined technical and a user’s angle within an experimental setting.

4.2. Lab experiment

4.2.1. Information seeking preferences in P2P systems.

With regard to information seeking preferences in Internet

⁴ e.g. <http://www.yahoo.com>, <http://www.google.com>

search engines, 98.7% of the participants are using keyword-based search strategies (51.2% rather seldom, 46.2% rather often, 1.3% exclusively), whereas only 71.2% (61.2% rather seldom, 7.5% rather often, 2.5% exclusively) are applying browsing techniques. These results reflect and confirm the predominance of focused fact-retrieving in the WWW as stated in several previous studies [34, 35].

Participants that were active P2P users (75% of the sample size) stated that 72.7% of their information seeking preferences in P2P systems account for *searching* (also referred to as search browsing [35]) with a well-defined goal in mind (i.e. finding a concrete and well-known search item [35]), 19.3% for *general purpose browsing* with a semi-defined goal in mind (i.e. consulting sources that have a high likelihood of items of interest) and 8% for *serendipitous browsing* with no goal in mind (i.e. purely random like for example checking out what additional interesting files a peer shares [35]). Detailed results can be seen in Figure 6.

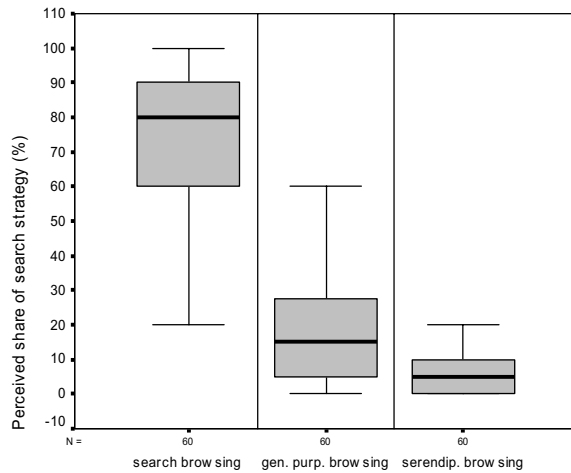


Figure 6. Information seeking preferences in file sharing systems

The evaluation of information seeking preferences shows that – same with searching in Internet search engines – a well-directed fact-finding strategy appears to be users' predominant approach to seek files in P2P-based file sharing systems. Most users have a clear notion of the searched items in mind before entering file sharing systems. A search strategy that may not to be neglected, though, is general purpose browsing, accounting for a fifth of the total search time in file sharing systems. In the face of these results, the question arises once again why file sharing systems do not offer complementary search functionalities known from Internet search engines to support users seeking in a general purpose browsing mode.

4.2.2. Influence of independent on dependent variables. In order to investigate the relationships

between independent and dependent variables in our experimental setting, we conducted multivariate ANOVA tests with SPSS, version 11.5.1 (see Table 3).

Both the specificity of the search task and the search functionality turned out to have no significant effect on the search efficiency. Nevertheless, both independent variables explained on average 9.9% of the variance of the search efficiency with a significant (corrected) model ($F=3.896$; $p<0.05$). A reason for the non-significance of each main effect was due to a significant interaction effect between the independent variables ($F=8.786$; $p<0.01$) indicating a high interdependence between search specificity and the applied search functionality.

The results of another multivariate ANOVA (MANOVA) test employing user satisfaction as dependent variable revealed that both independent variables explain 13.3% of the variance of user satisfaction leading to a highly significant model ($F=5.033$, $p<0.01$). While the factor "specificity of the search task" is significant at the $p<0.01$ -level ($F=9.32$), the factor "search functionality" is just significant at the $p<0.05$ level ($F=5.70$). No interaction effect between both independent factors could be stated ($F=0.08$). A closer examination of the profile diagrams of the MANOVA results revealed that focused search tasks and keyword-based searching are leading to a significantly higher user satisfaction than unfocused search tasks and network-based browsing. These results underpin the predominance of keyword-based searching activities with well-defined goals in P2P file sharing systems.

Dependent variable	Adj. R^2	Independent variable	F	Sig.
User satisfaction	0.133	Search specificity	9.323	0.003 ^a
		Search functionality	5.698	0.019 ^b
Search efficiency	0.099	Search specificity	1.217	0.273
		Search functionality	1.684	0.198

^a $p<0.01$, ^b $p<0.05$

Table 3. MANOVA analysis

In order to examine whether our investigated dependent variables are predictors for the actual usage intention, we additionally conducted a regression analysis (see Table 4).

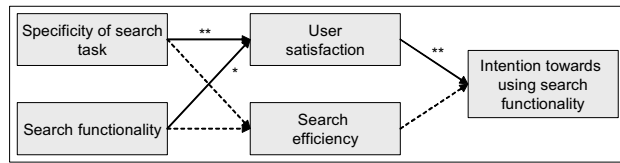
Dependent variable	Adj. R^2	Independent variable	t	Sig.
Usage intention	0.507	Search efficiency	-1.513	0.134
		User satisfaction	7.879	0.000 ^a

^a $p<0.001$

Table 4. Regression analysis

Just as expected, user satisfaction turned out to be a significant predictor of usage intention, while search efficiency didn't show any significant effect. Overall, as an interesting result of our study, search efficiency neither

could be explained by our independent variables nor predict the intention towards using search functionalities (see Figure 7). This implies that the intention to use search functionalities in P2P-based file sharing systems seems to be more dependent on perceptual constructs than on the time having spent for the search itself.



**p<0.01, *p<0.05

Figure 7. Influence of independent on dependent variables

4.2.3. Comparing searching and browsing efficiency. Regarding hypotheses 1a) and 2a), a t-test was executed comparing mean search time between groups I and III (focused search task) and groups II and IV (unfocused search task). Detailed results can be seen in Table 5.

	Focused		Unfocused	
	Task 1	Task 2	Task 1	Task 2
Searching:	Group I (n=20)		Group II (n=20)	
- mean time (sec.)	99*	138**	201	158**
	t=1.91	t=2.49	t=0.03	t=2.59
Browsing:	Group III (n=20)		Group IV (n=20)	
- mean time (sec.)	147	218	200	109
Absolute delta of mean search time	48	80	1	49

***p<0.01, **p<0.05, *p<0.1

Table 5. Comparative evaluation results: search efficiency

In both focused search tasks, users applying the keyword-based search fulfilled the search task significantly faster than users browsing through the semantic network. Hypothesis 1a) can therefore be supported.

Regarding the unfocused tasks, a more differentiated result could be observed. While no significant difference could be identified concerning the first unfocused task, users browsing through the semantic network fulfilled the second unfocused search task significantly faster than users retrieving information with the keyword-based functionality. These heterogeneous outcomes may be attributed to the different degrees of specificity of both unfocused search tasks. While for the first unfocused task the level of indeterminateness was moderate, for the second it was very high (see section 3.2.1.). In other words, users that had no idea about what keywords to enter could systematically browse through the semantic network until they had found an appropriate path to the

search goal. Users that had to enter keywords (group II) applied trial-and-error heuristics learning recursively from previous search results.

For the unfocused search task, it was hypothesized that browsing in a semantic network is faster than searching with keyword-based search functionality. Due to the ambiguous results, hypothesis 2a) must be treated differentiated. While for less unfocused search tasks (2a1), hypothesis 2a) must be rejected, it can be supported for highly unfocused search tasks (2a2).

4.2.4. Comparing user satisfaction towards browsing and searching. With regard to hypotheses 1b) and 2b), another t-test was conducted comparing mean user satisfaction between groups I and III (focused search task) and groups II and IV (unfocused search task). As it was based on two survey items, user satisfaction represented an aggregated construct. The results are illustrated in Table 6.

	Focused	Unfocused
Searching:	Group I (n=20)	Group II (n=20)
User Satisfaction 5-point Likert-scale (strongly disagree - strongly agree)	3.45 t=1.38	2.83** t=2.07
Browsing:	Group III (n=20)	Group IV (n=20)
User Satisfaction 5-point Likert-scale (strongly disagree - strongly agree)	2.98	2.23
Absolute delta of mean satisfaction	0.47	0.60

***p<0.01, **p<0.05, *p<0.1

Table 6. Comparative evaluation results: user satisfaction

Comparing searching and browsing in the focused search task, no significant difference could be observed, even though a tendency towards a higher user satisfaction for the keyword-based search could be identified. In the unfocused search scenario, however, users were significantly more satisfied with the keyword-search than with the ontology-browser. Both findings lead to a rejection of hypothesis 1b) and 2b).

Another interesting and quite evident result is that users using keyword-based search mechanisms showed a significantly higher user satisfaction in focused search tasks than in unfocused search tasks (t=2.13, p<0.05). The same results could be stated with browsing on semantic networks: Users were significantly less satisfied while fulfilling the unfocused search tasks than they were for the case of focused search tasks (t=2.19, p<0.05).

4.2.5. Implications. We could show that network-based browsing can lead to significantly higher search efficiency in highly unfocused search settings within P2P file sharing systems. For all other investigated search scenarios keyword-based searching prevailed with regard to search efficiency. In contrast to that, user satisfaction was higher in *all* scenarios including even the highly unfocused search task where browsing was more efficient. This fact is especially interesting as we could also demonstrate that not search efficiency, but user satisfaction is the key predictor of usage intention leading to a higher acceptance of search functionalities in P2P systems.

Having these findings in mind, the question arises why browsing in semantic structures results in a lower user satisfaction. Apparently, users basically feel more comfortable with focused search scenarios and well-known search mechanisms in the context of P2P-based file sharing systems. In opposite to what we had hypothesized, users were even more confused when an unfocused search task had to be fulfilled by using a browsing functionality. Our descriptive findings suggest that this may be due to the fact that users are simply not accustomed to browsing in Peer-to-Peer systems, an issue that could be compensated by learning effects. Another explanation might be that a multitude of topic map nodes in a semantic network leads to an information overload resulting into a “lost-in-space” feeling on the user’s side. This assumption is supported by the fact that the construct “user interface design” accounted for nearly 57% of the variance of the user satisfaction within group IV with a highly significant Pearson’s correlation coefficient of $r=0.752$. In contrast to the results for group IV, user interface design accounted just 15.4% of the variance of the user satisfaction within group II ($r=0.392$, not significant). These findings may also explain the plain user interface design of existing keyword-search functionalities in file sharing systems. Taking into consideration that these systems consist of a high number of concurrent users, the representation of peers as semantic nodes could be a severe problem to browsing user interfaces. With too many concurrent peers represented as semantic nodes in a GUI, users become disoriented because of the congested and overcrowded user interface in information-intensive environments. Different abstraction levels inherent in ontologies, however, could make sure that only a concrete domain of interest is displayed on the screen. Peers could be represented on the lowest abstraction level integrating techniques like SONS described in chapter 2.

The apparently high importance of user satisfaction indicates that a focus on the efficiency of file sharing systems is not sufficient. In fact, especially the user perspective is to be integrated to a much greater extent. In our experiment user satisfaction towards browsing on semantic P2P-based networks turned out to be low and

the attitude towards the user interface emerged as a strong and significant predictor of user satisfaction. One can assume that – by improving the user interface of browsing structures – the user satisfaction and hence the usage intention concerning browsing functionalities can be increased. If designers of P2P file sharing systems can take appropriate steps to positively influence browsing user interfaces accounting for the complex structures of P2P infrastructures, they could bring about positive user satisfaction leading to a higher user acceptance.

5. Limitations and further research

The discussion of the study’s implications demonstrated that a lot of further research remains to be done when applying the browsing vs. searching discussion on P2P file sharing systems.

In order to enhance internal and external validity, further experiments must be conducted including different search questions, varying browsing topologies (network-based, hierarchical, link lists, etc.) with customizable levels of abstraction, additionally controlled variables (e.g. intelligence) and a bigger sample size. The user interface we selected, although being implemented with frequently used open-source class libraries, was just one suggestion to realize browsing in file sharing systems, meaning the results should be interpreted carefully when extended to other search settings.

An alternative method to measure search behavior on semantic networks in P2P file sharing systems would be to introduce browsing capabilities not in simulated, but in real P2P applications over a longer period of time (longitudinal studies). Although certain variables could not be controlled (and measured) like in an experimental setting, the measured search behavior wouldn’t be distorted by an artificial setting.

Finally, integrating a combination of both search modes (searching *and* browsing) into one experimental design appears to be reasonable. One can think of a scenario where users with a rather rough notion about search items initially enter keywords to narrow down possible results. With a limited set of potential results, users may then browse through logically structured files presented by a semantically enriched P2P network.

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