Interactive Reading of Digital Documents in the Mobile Context

Master-Thesis

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Abstract

The increasing amount of available, digital information and correlated documents indicates their importance and an enrichment of their physical counterparts. Yet, there is an evolving offer of a manifold of digital and mobile devices, supporting users to access and manipulate digital information, allows the user accessing these information objects at any place and any time.
Still, users have to cope with limitations compared to the conventional paper-based complement's interaction approaches. Goal of this work is thus the limitation of interaction barriers by blending the digital and physical interaction traits of either world, to offer well-known behavioral types and to make use advantages of both worlds.

Zusammenfassung

Die zunehmende Menge digital verfügbarer Informationen und hiermit zusammenhängender Dokumente indiziert ihre Notwendigkeit und Erweiterung des physikalischen Pendants. Das zunehmende Angebot einer Vielzahl von digitalen und mobilen Geräten, die den Benutzern die Möglichkeit bieten auf diese digitalen Informationen zuzugreifen und zu manipulieren, erlauben dem Benutzer diesen Zugriff der Informationsobjekte an jedem Ort und zu jeder Zeit.
Dennoch stehen Benutzer Restriktionen im Vergleich zu den konventionellen papierbasierten Interaktionstechniken, ihrem Gegenstück, gegenüber.
Ziel dieser Arbeit ist daher die Limitierung der Interaktionshïrden, indem die digitalen und physikalischen Interaktionsgewohnheiten beider Welten verschmelzt werden, um altbekannte Verhaltenstypen anzubieten und die Vorteile beider Welten nutzen zu können.

Contents

List of Abbreviations

ANOVA analysis of variance
Methodology to identify differences between user groups and their related solution approaches.

DH dominant hand
Term considered for bimanual interaction and the user's handedness. The *dominant hand* describes the preferred hand of a user to make use of oneselves fine motor skills.

ISS information seeking and sensemaking
Process of identifying and resolving information and process the information to gain insight and interconnect the knowledge to other information artifacts.

NDH non-dominant hand
The *non-dominant hand* describes the non-preferred hand of a user to make use of oneselves fine motor skills.

KW ANOVA *Kruskal-Wallis* analysis of variance
Approach to analyze, whether user samples derive from the same population.

RBI reality-based interaction
Way to interact with (digital) objects in a realistic and well-known way from the physical world.

RMANOVA *repeated measures* analysis of variance
Statistical approach to analyze dependent variables for repeated measures designs (within-subjects user study designs)

TLX Task Load Index
Describing the subjective workload of a user with respect to six conditions

1 Introduction

One could assume, the reading activity is an archaic activity, which steadily evolved to what is understood of *reading* today. In fact, it has been strongly shaped by scholars in Greece or monks in the Middle Ages, just as it is influenced by the on wall paintings of the Egyptians or the stone engravings by stone cutters of the Maya, before it finally evolved into what we now understand by the term *written and spoken*.

Although the visual representation today stays the same, the process begins traversing a new development, similar to the introduction of pen and ink or the printing press. To what extend the real protagonist of this revolution, the reader, supports this evolution and if the reader is able to capable to master all inherent reading activities with this new technology will contribute to its success or failure. The talk is of the supposedly new technology, the computer (especially the tablet computer) and the associated inventions.

The enlarging amount of e-books, as textual digital media item, indicates the rising relevance of digital documents. In particular libraries are increasing their inventory with a raising amount of them [24, 46, 47]. Furthermore, the raising amount of purchased e-readers (which are obviously used for reading purposes) and tablet computers confirms the evolutionary process of new reading behaviors.[1]
Although this new technology came up so fast and was rapidly improved to fit a user's requirements even more, the way to interact with these digital representations just slowly evolves. The digital representation is well-known by many readers and also the touch technology has become more popular, as it allows a reader to manipulate and interact with digital content in a more direct way.
In either way, pure touch technology does not allow a reader to browse

[1] http://mobithinking.com/mobile-marketing-tools/latest-mobile-stats/a#mobiletablet, seen May 2013

and analyze a document's content on the way, a physical book empowers a reader. These well-known physical traits may be substituted or imitated in the digital world but still may fail, due to certain aspects. Aspects, such as emphasizing behavior or referencing traits, a user developed and improved over time. The idea is thus not to develop an interaction replacement of the physical world, but rather to enrich the digital world with well-known physical interaction traits by readers who have to fulfill more complex reading tasks.

At a first glance the activity *reading* is examined in detail, it is distinguished between different motivational factors and behavioral traits by readers. The introduction is used to identify and define requirements of readers and certain states of the overall *reading* process. The upcoming chapter 3 delimitss the domain of readers to libraries for scientific working purposes to understand readers who solve complex reading tasks.
With respect to the outlined evolution, it is examined what kind of opportunities *active readers* do have, but especially require and have to acquire to even enhance nowadays reading traits. These findings are used to develop a system, which aims to support a reading in *active reading* tasks to gather information and make sense of them to generate new knowledge. In a further step, this system is evaluated regarding its fitness for efficiency but also effectiveness and is herefore compared with conventional paper documents and a pure digital solution (see Chapter 5) to better analyze and compare it's suitability to available interaction approaches.

2 Active Reading

> to **read** /ri:d/:
> "{T}o look and understand the meaning of written and printed words or symbols [...] {and} to go through written or printed words, etc. in silence or speaking them to other people"
>
> *Hornby, Albert S. and Turnbull, Joanna* [25:1262]

The definition is covering two aspects of *reading*. On the one hand, it is mentioned to go through printed words, i.e. to gain information about a certain topic, when *reading* words. On the other hand, the understanding of a certain meaning is described, which – as consequence of information gaining – defines a process of gaining an insight with respect to the topic. Regarding Adler, *reading to gain information* and *reading to gain insight* are two (of three) main types of reading, which boundaries are blurred [2:22].
Adler broadens this expression, as the type of reading for *information gathering* does not equate the type of *gaining insight*. Nevertheless, the reader is able to distinguish how active a certain text or book shall be read and thus distinguishes how much an *insight is gained* or *information is just gathered* [2:22]. Based on this expression, *active reading* is considered as fuzzy term, a reader can read with a certain degree of activity, which is not binary at all. The degree of activity is the crucial factor for findings based on text. Furthermore, the third – an unambitious – reading type (*reading for entertainment*) is mentioned, where the user just enjoys a text's content (see Figure 1).

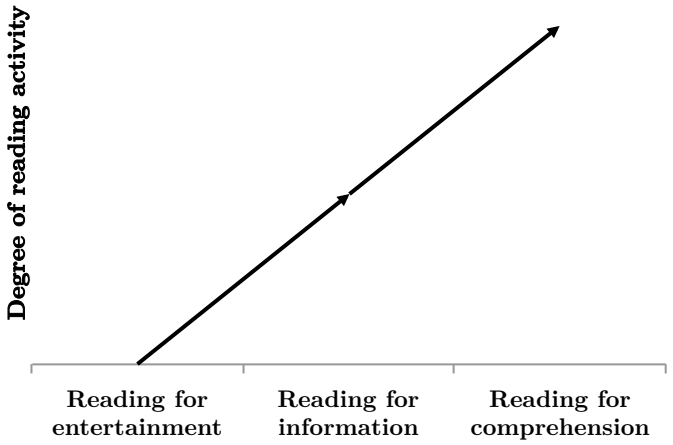


Figure 1: Classification of reading types with respect to the reading activity

In addition to the three main types identified by Adler: reading for *entertainment, information, comprehension*, four levels of reading are defined independently from the reading types. These levels build on each other and are necessary for a reader's reading skill [2:30ff.]:

1. Elementary reading
2. Inspectional reading
3. Analytical reading
4. Syntopical reading

Elementary reading Elementary reading is the basic *level of reading*. It describes the reader's ability for reading a text predominantly fluently, without being required to look-up unknown words or terms frequently. Furthermore, the reader has to be able to read a sentence as a whole, without stumbling over its syntax or grammar. [2:44]

Inspectional reading This reading level mainly focusses on the time component. The reader shall gather as much information as possible about a text to classify it's relevance as fast as possible. Therefore, the reader has to find out, *what* is written in the text. It is distinguished between two steps, which occur simultaneously: *systematic skimming & reading diffused* [2:22]. The *Systematic skimming* focusses on the book's structure and the

author's perspective, the reader shall investigate which parts would be of main interest for reading and hints to a specific topic.
Reading diffused demands the reader to simply read text passages until the end, even if certain parts were not understood by the reader. Later, the reader will *re-read* the text again with the knowledge of what the entire text is about, so understanding these former text passages is facilitated due to the known outcome.

Analytical reading If *inspectional reading* is classified as *time-efficient* reading, *analytical reading* would be classified as *effective reading*. Goal of this reading level is at first to understand the books content and further interpret it. An interpretation of text accompanies to argue with the text's content and meaning, but also with the opinion and point of view of the author. This process of judging a text is described as *critical reading*, but always postulates that a reader understood the text. A critical reader "evaluates the attempts of others to communicate with and convince their target audience by means developing a sufficiently strong argument"[61:viii], which implies that a reader mostly requires to inquire additional (information) sources for developing an adequate line of argument.

Syntopical reading After a reader has read a variety of books of the same domain, the reader is aware of the domain of interest and gained a certain insight. Goal of *syntopical reading* is to realize a specific intention of the reader (e.g. a presentation or a publication). The reader has a certain amount of formerly read information objects, which now shall be skimmed for retrieving the most relevant text passages for the reader's intention [2:34]. As the reader has to fuse different sources, the used terms of different authors have to be identified and integrated into one universally valid term. The consolidation of terms, claims and conclusions could then be used to generate new knowledge and pursue the regarded topic. The process of knowledge generation, based on self-learning requires to observe, remember, complement and fuse with own imagination of former findings.

Summarizing the requirements for improved text comprehension (with disrespect of the concrete reading level), *active reading* utters four questions, which the reader shall consider for understanding a text [3:318f.].

1. What in general is being said?
2. How in particular is it being said?
3. Is it true?

4. What of it?

These four questions cover the reader's tasks and are asked to reveal the quintessence of a read text and whether it is trustworthy or not to make sense of written text and process with it. Goal of an *active reading* support is thus to help the reader in finding the answers of these questions, not to answer the questions for the reader.

Because *reading for entertainment* requires the least degree of reading activity, the focus lies partially on *reading for information* and mainly on *reading for comprehension*. In the following, different user activities and methodologies are described to illustrate the correlated activities of *active reading*.

2.1 Behavioral Types & Methodologies

Different reading types and certain stages of reading skills and the corresponding classifications have been introduced that are essentially for *active reading*. In the following, procedures for *active reading* are presented, of how the *active reading* is performed by readers.

An important aspect for *active reading* is to mark relevant text passages, whether for understanding a certain text passage or for simply retrieving information later on. Marking of text passages is, nonetheless, performed on a vast amount of different ways, because of individual preferences or a divergency regarding the adequacy of each method. Here, a lot of different sources have collected the following approaches [1, 2, 42, 48, 57, 54, 64]:

1. Underlining
2. Highlighting
3. Formfilling of keywords / circled phrases
4. Vertical line at an abstract's margin
5. Note certain aspects at the margin
6. Bookmark most relevant pages (dog-ears or certain symbols)
7. Mark the author's line of argument by enumerating the arguments
8. Reference text passages among themselves, if it's content is associated

In addition to marking the most valuable information or for understanding the author's statements, readers might get stuck when interpreting or understanding a certain document of interest. Although the author's arguments are set in the correct order, people might simply not understand certain terms or passages and require to look-up a term, an interpretation or something else. Therefore, different textual types for reading support are listed to gain related information and insights [2:187-200]:

1. Field reports
2. Other books
3. Comments and other summaries
4. Reference guides
5. Dictionaries
6. Encyclopedias

Active reading presupposes a certain degree of activity by the reader. Gathering information and understanding a text for further sense making or creating an own textual work of interest requires more than looking up unknown text passages. Also rudimentary text markings are just one step to the *active reader's* goal. The reader requires to annotate own insights or important aspects with respect to parts of the text. These annotations are dividable into different types [2:65]:

Structural notes
: Annotations, which relate to a text's structure, the title, chapters or the author. The focus of the reader lies on this single text and it's composition. These annotations may also be used for understanding a specific argument of the author by referencing a text passage to one, formerly read in the document.

Conceptual notes
: In contrast to *structural notes*, the reader exhibits a certain degree of knowledge regarding the domain due to formerly read documents. The reader thus uses references across one particular document and is mainly focussed on the text's content than it's structure.

Dialectical Notes
: Assumed the reader has read multiple text's regarding a certain topic, annotations help the reader to set different lines of argumentation in context to fuse arguments and terms or criticize certain aspects.

Thematically, the annotations are tightly coupled to different levels of reading, because the procedural methods also raise in the regarded complexity. From regarding one single book, readers come across different books of the same topic and make sense out of them. Finally, the gained insight could be used to generate new knowledge or to criticize aspects. The following mapping of annotation types and reading levels is thus derived (see Table 1):

Level of reading		Annotation type
Inspectional reading	→	Structural notes
Analytical reading	→	Conceptual notes
Syntopical reading	→	Dialectical notes

Table 1: Key types of annotating (based on [2:65]) mapped to the Different levels of reading

The process of *active reading* has been regarded in detail. Operations performed by the reader are identified and different approaches for different stadia have been described with respect to the knowledge and reading skills of a reader. In the following the motivation for readers to actually *read active* is regarded to understand the reader's objectives and intentions.
The reader's purposes to interact with a document or a text may differ. Based on research data, O'Hara has collected different purposes for reading [41]. This amount of reading goals has then been limited due to a diary study to the following list of 10 goals [1] (see Table 2).
Obviously there is a range of various motivators for readers, also with respect to the degree of reading activity and also the reading skill of the reader. Nonetheless, these reading goals will finally be used to focus on very specific user requirements to support the reader with respect to it's most important reading goals.
This chapter is used to give a rough idea how complex the support of *active reading* is as a whole. Furthermore, that many different aspects and goals of readers have to be regarded.

Reading goal	Description
Reading in order to identify	A document is read, just in order to identify the type of document.
Skimming	Rapidly navigate through a document, to get a first impression of which passages are relevant and which aren't
Reading own text to remind	Reminding oneself for upcoming steps to do
Reading to search/answer questions	Reading for specific information required by the reader to answer a certain question or support decision-making
Reading to self inform	The reader aims to gain additional knowledge or information (not understanding)
Reading to learn	Reading in order to relate to gained information at a later point of time
Reading for cross-referencing	Information is integrated from different sources
Reading to edit or critically review text	(Critically) review a text with respect to certain aspects of quality
Reading to support listening	Referencing to a text source to trigger an argumentation

Table 2: Key types of annotating (based on [2:65]) mapped to the Different Relevant reading goals for knowledge workers [1]

2.2 Short Review

Active reading is performed with a varying degree of activity by a reader. Therefore, the *active* most reading types are considered (*reading for information* and *reading for comprehension*. Nonetheless, a good performance across various documents implies a certain reading skill to generate the output of desire. Although certain recommendations are given how to perform *active reading* with physical documents, a reader has to handle a high cognitive load. This load could possibly be decreased by offering a reader adequate functionalities to support different activities (such as annotating or referencing).
In the following a specific reader's domain is pierced out to further investigate an adequate user support of *active reading* in general and the mobile context in the following. Nevertheless, it is assumed that people are trained readers and are able to apply any reading technique across all reading levels.

A solution in the mobile context shall offer sufficient support for operational methods by the reader and not train the user in learning better reading or increase a reader's reading skill.
Then, a solution is examined, which covers the target reader's reading goals and offers an appropriate interaction technique, aiming to reduce a reader's cognitive load. This solutions is finally evaluated to estimate it's suitability for developing a design solution, which realizes the gained insights and supports *active reading* in an efficient way.

3 Domain Analysis

Nowadays, pads and tabs enable users to read digital documents in a mobile and paper-like manner and although the form factor is comparable to it's analog counterpart, users are still confronted with complex interaction (e.g. to leave notes or make annotations on the document)[26]. This is even more cumbersome when reading scientific documents. For example, a given list of references within a document forces readers to look up the literature on their own instead of accessing a selected item immediately.
The increasing amount of e-books, as textual digital media items, indicates the rising relevance of digital documents. In particular, libraries extend their inventory with a raising amount of them [24, 46, 47]. Digital libraries take advantage of time- and location-independence and the ability of management and manipulation of a vast amount of documents and functionalities offer [5, 19], such as text search and annotations.
While the accessibility of digital documents is provided through customized search engines for libraries with an individual result representation, the media object itself is mostly provided in a proprietary file format. While the search algorithms and visual appearances of the search process are optimized, the library is not able to take care of an enriched functionality of these files, hence it just provides the consumers with their products. The users of these products thus require adequate information and communication technologies to work with these documents in an ergonomic and efficient way, which is rather granted by making use of tablet computers [41]. Further evidence of the increasing appeal of tablet computers is given by the forecast by Gartner[2], which describes the rise of worldwide sales by more than 2.5-fold.
In either way, the techniques to access and work with the content of these digital media items has to meet the requirements of users, to support them in the information seeking and analysis process while ergonomic aspects of the human computer interaction are fulfilled.

[2] Forecast: Media Tablets by Operating System, Worldwide, 2010-2015: http://www.gartner.com/it/page.jsp?id=1626414, seen January 2012

In case a user wants to retrieve referenced literature from a relevant document, certain tasks have to be regarded. At first the literature reference has to be resolved within the document (for example [1] maps a certain document and author). As a second step the user looks for the document, in the library's catalogue or any other search engine. When the document is finally retrieved, the reader scans the document for the correct text passage to gain additional insight.
Because readers are used to retrieve documents in libraries (whether conventional or digital libraries), the term *library* will be defined in the following and it's domain examined. The examination focusses on analyzing user groups and their personal needs, which will be mapped to identify *active reading* requirements (see chapter 2.1).

3.1 Blended Library

> "The library is the only **centralized location** where new and emerging **information technologies** can be combined with **traditional knowledge resources** in a **user-focused**, service-rich **environment** that supports today's **social and educational** patterns of learning, teaching, and research."
> [Emphasizing was done by the author, T. B.]
>
> *Freeman, Geoffrey T.* [17]

Regarding the definition given by Freeman, several key aspects are taken into consideration for conventional, academic libraries. Digital libraries extend the key aspects of conventional libraries, as they are location independent and do not make use of traditional knowledge resources, but digital knowledge resources (including digitized media items of their traditional counterparts). So, the following list of key aspects is derived for the term *library* in general:

- Information Technologies
- Knowledge resources
- Location awareness
- User-focus
- Educational patterns
- Social patterns

A mixed library thus covers traditional media items (such as books, printed copies or sketches) but also a vast range of digital documents (e-books, websites or online publications). This is also a reason why readers often have to cope with both kinds of documents today, when working with documents. While users are very aware of how to interact with physical objects, the interaction with digital ones differs. If this reality-based interaction (RBI) was transferred to the digital world, the interaction would keep its expressiveness, but would lose the power of the digital world and thus lose certain advantages, as text search or links within and between documents [28].
Currently, the reader's personal favor of physical or digital interaction possibilities causes users to digitize physical documents or print out digital elements (see Appendix 6.1), which causes a media discontinuity and a loss of advantages of either world. Although this discontinuity allows readers to work in a proper way regarding their habits, their current working context is disrupted due to the media transformation process.
To now allow users to keeps their common physical traits but also not lose the power of digital items, there is a need for an approach that allows an interaction, similar to the RBI approach, but also keep the advantages of the digital world. In 2008, Jacob et al. defined a framework including four themes of RBI for emerging interaction styles with computers, which are close to the ones of the real world [28].
To generate interaction techniques from the RBI, the domain *library* and it's four themes are analyzed for deriving a correlated interaction approach with respect to each theme. Each theme relies on the pre identified key aspects of a library, so the following mapping is deviated:

Key aspect		RBI theme
Information Technologies & knowledge resources	→	Naïve Physics
Location awareness	→	Body Awareness & Skills
User-focus	→	Environment Awareness & Skills
Social patterns	→	Social Awareness & Skills

Table 3: Mapped key aspects of libraries to the themes of reality-based interaction

While the key aspects' terms are easily mappable to the themes of the RBI, the atomic sub-aspects of the key aspects have to be regarded for an assignment in detail. For example, the term *user-focus* summarizes a variety of sub-aspects that have to be taken into consideration, such as the user's physical conditions, the constraints in mobility and place. A visitor of a

library may have a working place, which is restricted to $2m^2$, which might not be enough for a huge amount of physical media items required by the reader. So the domain of the *library* will be examined more detailed in the following to provide an overview of user groups in libraries and their requirements. The insights will be used for a mapping of the RBI themes to a specific target group and one of it's characteristic tasks. This very specific transfer will not redefine the being of the whole library as such but is seen as a brick in the term *"Blended Library"* that illustrates a mixture of the benefits of both physical and digital worlds across the physical compendium of a library [5].

Hence the key aspects of a *library* and it's domain are classified, the consumers and their behavior will now be regarded in detail. Therefore, the users' motivation and their intentions have to be understood to make use of knowledge resources in a library. At first, the different motivational factors of visitors are identified. Afterwards, the main target group to focus on is selected, which users are mainly motivated by *active reading* purposes.

In addition to the identified user groups, there are also five types of user activities identified, for which libraries would need to be designed [45]:

- Information Seeking
- Recreation
- Connection
- Contemplation
- Teaching & Learning

Information Seeking: Information seeking describes a process of engagement by people who want to gain insight in a specific topic. Information seekers have a certain point of interest and thus some kind of background knowledge of what they are looking for. Nonetheless, there is no final state where they feel like knowing everything about a certain topic [34]. For gaining additional information related to certain domains, they require at first a point of entrance for a search and later on additional background information. The related information material may either be introduced by former media items (for example reference lists) or by a result representation of the library with items, suggested based on the search request.

Recreation: Recreational activities are motivated by enjoyment and pleasure. Visitors require different types of media items and infrastructure. For example, they might want to access a movie as fast as possible and watch it or simply browse through the web. Another kind of recreation could be the participation in library activities, such as author lectures. Regarding the *active reading* purposes, recreational seekers are mainly reading for leisure. Nonetheless, this reading activity and it's gained insights might be relevant for the reader's purposes and might be relevant for upcoming working processes.

Connection: Information and idea exchange is an important aspect, whether in the academic context or for cultural exchange. The library takes place as meeting point and provides an environment to start and support conversational purposes either between friends or between visitors with same interests or backgrounds.

Contemplation: From time to time visitors just require the library to behave as refuge, which forms a place to provide a silent environment, described by Tisdale as followed: "Its silence–outrageous, magic, unlike any other sound in my life–was a counterpoint to the interior noise in my crowded mind."[58]
Furthermore, visitors reflect reviewed media items or thoughts, especially in the academic context when thinking about a structure of a homework.

Teaching & Learning: While these terms mainly rely on the academic context, any visitor or group of the public context my take place here. For example, people meet in the library due to it's infrastructure that provides public meeting forums or displays. This may be used either by student work groups or other public visitors because of the library's high accessibility, where it's services are free or inexpensive [31].

There are eight different types of user roles identified in an explorative study investigated by the *Institute for Learning Innovation and Delaware Division of Libraries* in 2009 [16]. Visitors of a library were asked to state their motivation for visiting the library at this day. Based on these reasons, eight different user groups were generated, to which the reasons are assigned.

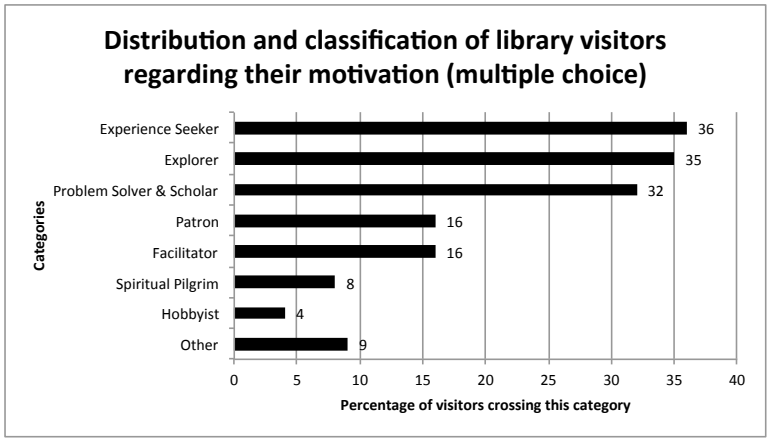


Figure 2: Distribution of classified visitor groups of the Dover Public Library by their motivation

With respect to the user activities and user groups, the most important user group with the focus of *active reading* is retrieved to analyze it's *active reading* related work processes. Regarding the distribution among the eight classified user groups (see Figure 2) the most common ones are analyzed that occurred 99% of the time:

- Experience Seeker
- Explorer
- Problem Solver & Scholar

Experience Seeker: Experience seekers' main intention relies on knowledge transfer and communication. They participate in communities and groups to discuss with each other or for presenting and listening to talks while also intercultural interests and exchange stay in focus. Regarding the identified user activities by Peterson, *experience seekers* are predominantly assigned to *connection* activities. While *connecting* is the user's main interest, *recreation* and *information seeking* are also covered. In contrast to *contemplation*, *teaching & learning* is slightly part of their activities, thus they use the library for information exchange and experience (see Table 4).

User Role	Experience Seeker
User Role Properties	° Personal commitment ° (Inter-)Communicative ° Enjoying learning & reading ° Active knowledge transfer
Assigned User activities	→ **Connection** → **Recreation** → **Information Seeking**

Table 4: User Role – Experience Seeker

Explorer: The library is used as refuge for reading and browsing through its collections by the *explorers*. They focus on their personal interests, which are mainly informal. When visiting the library in their spare time, they stay in passive contact to the library, relying on notifications. For example, they read a news page by the library or are subscribed to a library newsletter. Regarding current events of the library, they also take part as passive actors, when they attend to read-aloud evenings and such. Their main purpose is thus a passive information exchange and also some entertainment intentions, so the user activities *recreation* and *contemplation* are assigned to these purposes (see Table 5).

User Role	Explorer
User Role Properties	° Individual working (require quiet rooms) ° (Intra-)Communicative ° Audio files or read-aloud as alternative to reading ° Require recommendations to events & reading ° Passive knowledge transfer
Assigned User activities	→ **Recreation** → **Contemplation**

Table 5: User Role – Explorer

Problem Solver & Scholar: Researchers and students are classified by the Institute as *problem solvers & scholars*. They require latest literature and are thus dependent on both internet access for online resources or digital media items and access to conventional knowledge resources such as books, journals or newspapers. In addition, they require search engines for

further media items and suggestions based on content correlation or on collaborative filtering[3]. Finally, they need to manage both the large amount of data they are able to access and their own inventory of considered relevant literature. So, the user should not lose the current context of the search, while accessing related material [54]. Furthermore, they are also in need of referencing their related information objects to each other by classification or correlation.
Their focus lies on *information seeking* and *teaching & learning* but also on the reflection of their course of action and structure of textual work (see Table 6). These activities are part of gross strategies, developed to guide one's own progress in scientific working [34].

User Role	Problem Solver & Scholar
User Role Properties	° Research needs ° Require access to online resources ° Computer based lookups, working ° Require Recommendations to events & reading ° Need of guidance for reference literature ° Handle large amount of media items
Assigned User activities	→ **Information Seeking** → **Recreation** → **Teaching & Learning**

Table 6: User Role – Problem Solver & Scholar

With respect to the most frequent user groups corresponding user activities were assigned. This classification is now used to regard the user group, which users require the most to *read active*.

This chapter described the domain and context of a common library, which is enriched by the digital world and its possibilities. Well-known RBI techniques are limited in the digital world and a transfer to the digital world has to be investigated for keeping the digital world's advantages. This investigation aims at the specific user group of researchers, which users are frequently performing *active reading* tasks in every day's working processes and highly affected by an integration of digital documents in their processes of scientific working.

[3] "Collaborative filtering explores techniques for matching people with similar interests and then making recommendations on this basis."[33]

3.2 Scientific Working

So far the user group *researchers* is determined, which working behavior related to the library is further investigated. The relation of the user group to the library is both highly and loosely coupled, as users are directly affected by the library as a place to work and meet other people. In addition, researchers do not only work in one single location. Furthermore, they rather work in additional places and require to use and access a system at any place, even though the system is just partly portable [5, 57]. For additional insights, an explorative user study was accomplished regarding the target user's work flows and their working behavior. The study covers the following three data acquisition aspects and was conducted:

1. **Questionnaires** were laid out in two academic libraries[4] to investigate the group work behavior of library visitors. The behavior was examined regarding the amount and frequency of group meetings and the user's motivation for the meeting (see Appendix 6.2). Furthermore, the required resources and materials were recorded regarding either necessity of the participants.

2. **Interviews** were held in both universities (Tübingen and Konstanz), to provide a better basis regarding the working places of researchers and students. The former questionnaire was used as interview guideline. For additional insight in the scientific working domain, further inquiries were called by the interviewer.

3. **Focus groups** were held with a group size of three students who discussed their group work behavior regarding their attitudes and requirements. The synergy of their perceptions and opinions was used to accomplish a widely covered scientific working behavior with respect to the individual circumstances, requirements, behavioral types and working procedures.

The main findings of the accomplished study illustrate the researchers individual - and group working behavior. Regarding the results, researchers meet another to assign tasks and share gained insights but work individually to prepare their results and to explore certain information spaces. This results in an alternating order of individual - and group working sessions, while the initial and final sessions are used to be group work ones. So individual working sessions are mostly embedded into group working sessions

[4] *Tübingen University Library* in Oct. 2011 and *Library of the University of Konstanz* in Dec. 2011

(see Figure 3). The shared knowledge and exchanged insights of researchers are then used to assign new tasks within the group or to continue with former group work processes. The amount of occurring individual and group work sessions strongly differs and is based on the group's goal and members. For example, a continous learning group meets regularly over the semester, while a group for a scientific report rather meets infrequently and for a shorter period of time.

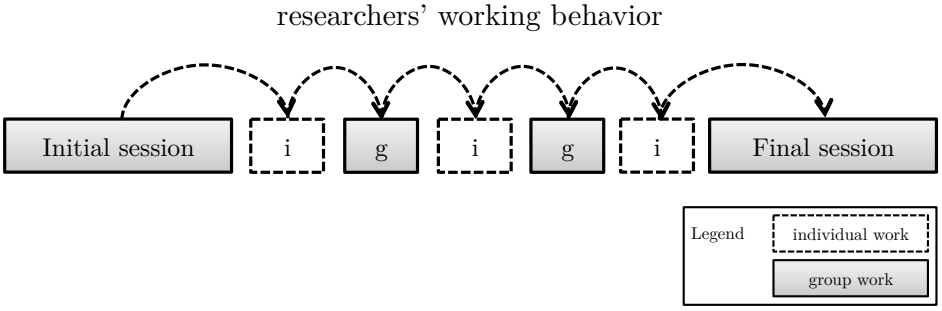


Figure 3: Researchers' working behavior regarding individual - and group work

Both working phases differ in the researcher's line of action and are thus regarded separately. Therefore, the occurring main processes that are related to either working type are examined regarding the user's activities and the resulting, specific requirements.
Because problem solvers and scholars "concern themselves with the analysis of text"[13], the *information analysis processes* is examined in detail. The information analysis in general, hence media items may also include other information representation formats than text and text is just a more specific representation of information in general. Isenberg et al. identified eight key processes covered by the information analysis, which have to be taken into consideration when analyzing information in the individual - and group work context (see Table 7).

Process	Description	Goal
Browse	Scan through the data	Get a feel for the available information
Parse	Reading and interpretation of the task description	Determine required variables for the task
Discuss Collaboration Style	Discuss task division strategy	Determine how to solve the tasks as a team
Establish Task Strategy	Establish how to solve a task with given data & tools	Find an efficient way to solve the problem
Clarify	Understanding the data	Avoid mis-interpretation(!sic) of the data
Select	Pick out information relevant to a particular task	Minimize the number of visualizations to read
Operate	Higher-level cognitive work on specific data view	Solve task or sub-task
Validate	Confirm a partial or complete solution to a task	Avoid errors in completing the task

Table 7: Processes in information analysis (based on [26])

Isenberg et al. also analyzed the behavior of students as users of the target group *researchers* in an exploratory study. The study inspected the visual analysis processes of users in individual and group work processes. Based on data of the observational study, eight identified processes are assigned to the working constellation, in which they occurred most frequently.

Browse As opposite of analytical search processing, *browsing* relies on the information environment. After determining an entry point in the information environment, the user scans opportunistic and informal through the landscape and retrieves or refuses information objects [34]. *Browsing* did take twice as much time in individual work settings than it took in group work. It is more relevant for individual working processes, although it did also occur in group work. With respect to former identified user

actives of researchers in libraries, this process is seen as relevant for *active reading* tasks.

Parse The *parsing* process focusses on retrieving relevant information for a given task to find a solution. The user examines given information objects in detail to get an impression of its content. Regarding the accomplished user study, *parsing* takes place in both kinds of settings, but did occur more frequently in the individual working phase and is thus allocated to the individual working constellation.

Select After an information artifact is understood, its relevance – regarding the task that has to be solved – is set. Either an artifact is relevant enough to be classified as relevant for the task's solution and thus *selected* or classified as irrelevant and refused. As both working constellations (individual and collaborative) had to solve given tasks, this process occurred in both and is considered as relevant for both. Nevertheless, the formerly investigated exploratory study demonstrated that this process is more relevant in individual working phases and thus assigned to the individual work.

Operate The *operation* with information artifacts, such as data extraction or data comparison, requires higher cognitive load and also leads users to annotating the information artifacts. As annotating is also an aspect of *active reading*, this process is considered as highly valuable. Regarding the assignment to an individual - or group work constellation, it is the same phenomenon as the selection process: this process is more relevant in individual working, so it is more important for individual workers.

Discuss collaboration style Obviously, this process did just occur in the group work constellation, as users *discuss* here their collaboration strategy. While there is distinguished between several group work procedures, *active reading* is not further regarded in this organizational work process.

Establish task strategy The approach to find the best way to solve a given task occurs in both constellations. While group work researchers rather discuss their approaches, individual workers have to reflect their solution on their own. As identified earlier by the library user groups, the reflection of the course of action is necessary for example for the structure of textual work. This working process occurred most of the time in collaborative settings, although individual working users were thinking aloud and thus describing their current thoughts regarding their *task strategy.*

Clarify After retrieving an information artifact, readers have to be aware of the artifact's content. To do so, they try to understand the content. In case a user stumbles over a word, which is unknown, the meaning of the word has to be understood. Furthermore, the word is set into context of the information artifact. The observations of the study show that the *clarification* process is mostly performed as group work in discussions and thus allocated to group work. In individual work, users tried to understand the meaning by using additional information artifacts or simply refused the unknown information artifact.

Validate The validation of solutions for a specific task is more common in group work constellations. Users present and discuss a certain solution to validate it's correctness in team collectively. In the individual setting users validated their solutions by comparing chosen information artifacts with other data sources. As the collective discussion took more time than the individual *validation*, this process is rather assigned to the group work setting.

Individual work	Browse Parse Select Operate	
	Discuss collaboration style Establish task strategy Clarify Validate	Group work

Table 8: Classification of visual analysis processes to individual and group work

The most relevant *active reading* related processes (especially *parsing* and *selecting*) are anchored in an individual working constellation (see Table 8). To focus on individual working as more important work setting for *active reading*, frequent work processes of individual working are further regarded and investigated. The following four processes of individual work describe the different states and phases, an information seeker (researcher) passes [30]:

1. Browse
2. Parse

3. Select

4. Operate

When the gained insight of researchers regarding their task solution is evolving, their singular processes cover different needs. These four main processes regarding the individual working phase are further examined in detail in the following.

Browse

While search strategies cover two types of strategies, analytical search strategies are not further regarded and the focus lies on browsing, as it is part of the individual working processes for visual analysts. In contrast to the analytical search strategies, browsing is more informal. It is not as goal directed as users expect certain results when looking for search terms in a search engine. So the motivational factors of browsing differ from those of analytical search strategies [34]:

- Gain an overview
- Monitor a process
- Discover & learn
- Environmental invitations

Based on key factors of a certain information item, such as meta information, it's media type or it's physical shape, users gain a first impression of a certain topic [55]. Furthermore, users browse to orient themselves in a given information environment. For example, a user needs to be aware of the current position in a document, the current chapter and page and the progress within a document and how many lines are left in an abstract. By rereading, users also reflect what they have read before, to go into more detail or to better understand the text. Rereading may also be performed across multiple chapters or documents, to recapitulate a certain topic [19]. On the other hand, related information artifacts that are highly relevant for the solution may be found in the browsing process, which might not have been found by an analytical search strategy. This might be due to other search criteria, the user would have used, as key words or classifications might differ.
Finally, the environment has to support browsing in a sufficient way. In

most libraries, for example, users are able to browse a large amount of media items (such as books, videos or newspapers) in bookshelves, which are arranged with respect to the books' classified topic. The digital representation of media items provided by a library are visualized through linking related literature with each other or to list the items close to each other. For example, a recommender system could offer a catalogue of additional reading literature, which is related to an original file by content, author or publisher.
With disregard to the realization of a browsing supported environment, the user's motivation for the browsing process is considered to better understand the requirements. Regarding Gutwin et al. there are three task types identified in digital libraries, which users practice and a system has to support to provide the user with a sufficient browsing environment (see Table 9) [20]. The approach describes the user's tasks with respect to the information environment the user wants to browse through. While, the *collection exploration* bases on the whole amount of information objects (described as *macro layer* in the following), the user gains a rough idea of the topics, covered by the collection. To valuate a specific object's relevance with respect to the topic, the information seeker examines information objects in detail (*micro layer*). As a consequence of the search behavior on a single item and the whole item collection, the user requires to rephrases the query to retrieve additional documents and refuse unnecessary items.

Task type	Question
Collection evaluation *Macro layer*	What's in this collection? What topics does this collection cover?
Subject exploration *Micro layer*	How well does this collection cover an area X? What topics are available in area X?
Query exploration *Intermediate layer*	What kind of queries will succeed in area X? How can I specialize or generalize my query?

Table 9: Task types of browsing (based on [20])

These task types by Gutwin et al. describe certain states, the reader passes, when browsing through a data collection. While the different user tasks are in focus, the transitions or user actions between the task types are missing. For example, a user skims trough a list of content-related media items (*collection evaluation*) and wants to access a certain media item for further exploration (*subject exploration*), the expectations and requirements of the user are not examined in detail. To enrich the task related approach by Gutwin et al. with the corresponding transitions, an activity related

approach is considered additionally. Rice et al. describe goal-driven user activities with respect to the corresponding type of explored objects (see Table 10) [51:255]:

Scanning	Resource	Goal	Object
Looking for	Meta-information	Locate	Specific item
Identifying	Object (whole)	Evaluate	Common items
Selecting	Object (part)	Keep up	Defined location
Examining	Information	Learn	General

Table 10: Activity related goals and objects of browsing (based on [51])

With respect to the states of the browsing process, represented by the task types, the information seeker's activities are set into context of the information landscape. The activity of *examining* requires information of objects to identify a certain topic or to further classify the information object in a categorization applied by the user. Thus, it is part of the *macro layer*, as the information collection and its overall information objects are regarded. When *selecting* a specific part or passage of an information artifact, the researcher performs on a low granularity layer and accesses detailed data of a specific object. Derived from both layers, the high granularity and the highly detailed one, the information seeker moves between both the collection evaluation and subject exploration. This intermediation between both is formed by the redefinition of the query and it's evaluation. To do so, the researcher requires on the one hand meta-information of information objects to further specify the query, but also enough information to locate a specific item. Both activities (*looking for* a specific item and the *identification* of information objects) transition between both layers on the *intermediate layer* (see Figure 4).

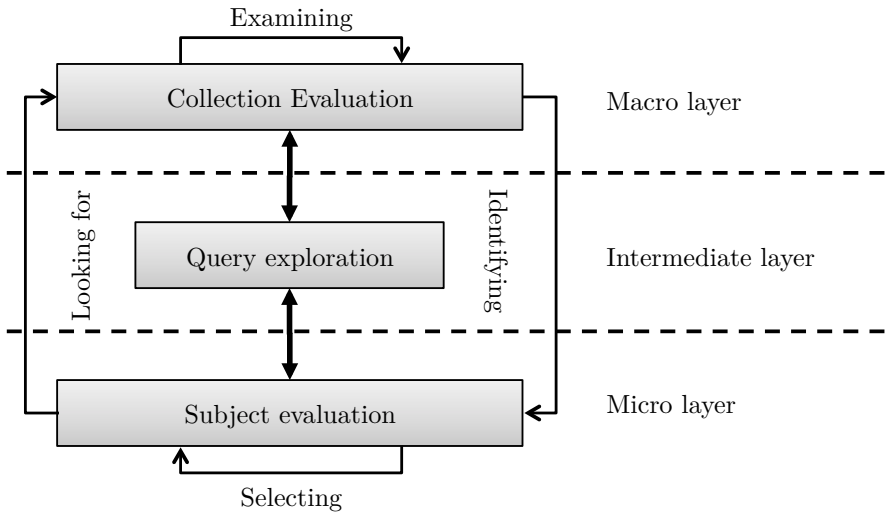


Figure 4: Model of Information collection granularity for browsing tasks

Browsing is considered rather as circuit than as sequential process. Different stages across different information environment granularities have to fit seamlessly in the user's context and cover the information seeker's needs.

Parse

After an item is retrieved and opened, it's content has to be understood for further processing. The content's representation – especially in the context *(blended) library* – covers different media types, such as text, images, videos, sound files or a combination of them. In the following, we will focus on textual representation, hence it is represented the most in the investigated academic libraries[5], whether as book, journal or electronic document.

> "Fundamentally, the process of understanding a work implies a re-creation of it, an attempt to gasp completely the structured sensations and concepts through which the author seeks to convey the quality of his sense of life. Each must make a new synthesis of these elements with his own nature, but it is essential that he evoke(sic!) those components of experience to which the text actually refers."
>
> *Rosenblatt, Louise M.* [52:113]

[5] http://www.bix-bibliotheksindex.de/de/ergebnisse/oeffentliche-bibliotheken.html, seen February 2012

In order to make sense of a document's textual content, the reader requires to *parse* the textual information to set the information into context. Just like the *browsing* process, the process of *parsing* is split up into several, sequential tasks, the reader accomplishes (see Figure 5). In contrast to the first three tasks, which are mainly influenced by linguistic factors, the word-to-world mapping is affected by the reader's experiences and context, which evolves with insight gained of a topic:

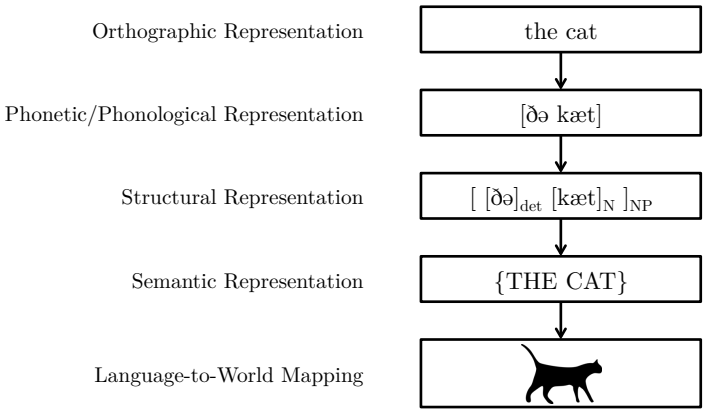


Figure 5: Sequential steps a reader processes to understand written language (based on [50])

With respect to the states a user passes when understanding written language, there are four occurring transitions taken into consideration. Hence a transition takes place between two steps, errors in the transition process might occur. These errors – especially the corresponding transitions – have to be understood to avoid an error prone understanding of text by the reader.

1. Orthographic representation → Phonetic/Phonological representation
2. Phonetic/Phonological representation → Structural representation
3. Structural representation → Semantic representation
4. Semantic representation → Language-to-World mapping

Orthographic repr. → Phonetic/Phonological repr. A possible failure that might occur in the transition from the orthographic representation to the phonological one is caused by an unknown word, as readers rely on

their experiences to obtain new understandings [52]. The reader would have to guess how to pronounce the word correctly and might identify it's meaning. To support a reader in this early phase of processing, the reader shall be able to access certain resources to get an understanding of the word and continue reading, for example a glossary or the opportunity to listen to the pronunciation.
Nevertheless, this potential failure is somehow acceptable for different reading states, for example, for understanding a document's structure a reader is skimming the content systematically and does not have to be aware of each detail.

Phonetic/Phonological repr. → Structural repr. The second transition of processing written language might fail due to misassigning a sentence structure (because of ambiguity, as it is the case for prepositional clauses), which would lead to a misunderstanding of the sentence. As this syntactical and structural ambiguity is yet a deep linguistic problem to be solved and the work focusses on supporting *active reading* and an appropriate interaction technique in the mobile context, this very elementary problem will not further be regarded.

Structural repr. → Semantic repr. The semantic decoding describes the interpretation of words. Due to the ambiguity of some words, readers have to dissolve ambiguous word meanings. For example, the word "bank" is a syntactical noun, but it does not provide any information about its meaning (either as institution or as bench). The correct assignment is correlated to the correct analysis of the words' context, the sentence structure and – as the structural representation problem – yet to be solved by linguistic experts. Thus, it is not taken into consideration for the *active reading* supporting solution for digital documents.

Semantic repr. → Language-to-World mapping The errors of the transition to the word-to-world mapping occur because the user is not able to map the semantic representation to the real world. Regarding Busse, this part of text recognition is generic for speech recognition in general [7]. To solve the problem of unknown terms or interpretations, readers require additional information to support the process of understanding. For example, the support might be established through offering a glossary or dictionary. For more complex terms or sentences, additional or referenced literature could be provided as further resources, to get a deeper insight.

Regarding the *active reading* support for readers of digital documents the process of textual understanding shall be supported. For this purpose, both subprocesses of getting the *phonological representation* and the subprocess of retrieving the *word's world mapping* are further regarded. The support for the correct understanding of the text's content is thus dependent on provided reference material and dictionaries or glossaries, with which the reader would easier be able to get the correct meaning of the textual content.

In addition, Isenberg et al. identified two ways of navigation with respect to navigational strategies in the visual data analysis process [26]:

- Depth-first
- Breadth-first

Depth-first The *depth-first* approach describes the strategy to focus on one specific artifact and the continuous working with the item for a certain period of time. The reader sticks to a currently selected item and finishes the item analyzation process at first. Afterwards, related information objects may be considered for deepening the insight of a specific topic, in case additional information is still required or the need to read referenced and correlated literature occurs. In the following this behavior is called *focussed reading* and mainly aims to understand the focussed issue.

Breadth-first Regarding the *breadth-first* approach the user interacts with several items in parallel. To support this in an adequate and sufficient way, users shall not lose the context and document of origin. For example, a user might cross an unknown term in document A, which is defined in another document B. Although document B defines the required term, additional information, related to another topic might be covered and interesting for the reader. This diffusion might lead the reader to continue reading in another related document C and lose the context and the document of origin. The reader chooses to broaden the knowledge and gets additional background information regarding a certain domain or across domains, until a certain point of time, till the reader returns to the original document. In the following this behavior is called *diffused reading*, as it is defined by Adler (see Chapter 2).

To get an understanding regarding the necessity of both navigation strategies, data regarding the overall occurrence of researchers' navigation behav-

ior within and across documents requires to be acquired in a requirements analysis.

Select

The user thins out the collection of information artifacts in the *selection* process. It is based on the browsing activity, as specific information objects have yet been taken into consideration by the researcher. The selection of these preselected information objects aims on the decrement of the information object collection, which contains the most relevant information artifacts. For example, the information object might be sorted out, because it is not required anymore or because it covers a wrong topic. We will distinguish between *document selection* and *content selection*. The *document selection* aims to sort out irrelevant document for further processing. *Content selection* is used to extract information from relevant documents and set these information into context to build new schemata.

Document Selection

As the selection process is performed on the results of the browsing process, a certain amount of preselected information objects forms an individual set of information artifacts. To sort certain information objects out, the user requires to get an overview of the objects and their content. Therefore, users separate certain information artifacts from each other, as they may have pre-identified an object as relevant, but still want to compare it to other ones. This classification and clustering of objects is for further processing and operating or for the simple rejection of information artifacts used to create a mental structure of the document. This process is accomplished in two ways. For keeping an overview, users rely on either fanning their information objects out or by piling the information objects into clusters [26]:

- Fanning out
- Piling

Fanning out The distribution of information artifacts among the workplace provides the advantage of direct comparison of certain objects either for a certain topic or chapter or because they are not relevant anymore due to the evolved insight of the researcher. So the relevance and quality of artifacts is directly measured and can be compared across certain parts.

To support the fast comparison of certain topics related to the information objects, users shall be able to access relevant text passages.

Piling As tasks of researchers require to be split up into several chapters, an ability of information classification is needed as well. For example, an elaboration consists of chapters, definitions or simply related work, which the scientist requires to assign to certain areas of a mental model. Isenberg et al. defined this behavior as *piling*, because users piled correlated information objects, as they used a square card format (comparable to memory cards) for their information artifacts [26].

As the collection of the information was performed in several states of the research activity, artifacts were collected and certain topics were considered to an individual data set. To support both activities of information artifact selection, an appropriate system shall be able to react on the user's needs of sorting and rejecting objects [44].

Content Selection

While the object selection – based on comparing between information artifacts – has been investigated, the selection of relevant parts or text passages from information objects is further described. As formerly described (see section 2.1), it is accomplished by text selection but also requires bookmarking and back-tracking to the appropriate abstract [1, 64]:

- Highlighting
- Note-taking
- Form-filling (circles or brackets around relevant text passages)
- Document reviews and document notes
- Copy & Paste into another document

While the need regarding text passage selection is considered, users should be able to get back to the related information object. The advantage of back-linking describes the fast accessibility, when users require additional information of the information object or simply want to refuse it, in case, the information is not required anymore. Furthermore, the post processing of selected text passages requires the ability to move selected passages around for applying the selection strategies (*fanning out* & *piling*)in an own mental model [38, 40]. In either way, a user requires to access correlated information

objects and shall not be restricted by navigation barriers across related information artifacts.

Operate

After different information objects and sources have been acquired and accessed, the reader gained an insight in the theme. The researcher now starts to fuse different sources to cluster and classify them in order to find or build schemas of an individual model [53]. This operation with single media items or selected information artifacts is called *operating* and varies over different stages of the information seeking processes, as sense makers now recode the selected information into own illustrations. Finally, the original documents are re-examined to validate the information schema and thus also require here the formerly described back-linking to the original source.

Integration of Scientific Working into the Blended Library

As the researchers work processes have been examined in detail, the interaction with digital documents with respect to these processes is considered in the following. While physical documents offer the ability to interact in an informal and unplanned manner, digital documents mostly empower the readers to gather objects, clip information or also annotate documents [35]. Related to the information seeking and sensemaking (ISS) activities, Evans and Chi developed a model that sets atomic tasks into context and illustrates the work flow of researchers as a whole [14]. This model is used to integrate the regarded tasks for *active reading* in a researcher's workflows of digital documents in the mobile context with respect to an appropriate interaction technique based on the themes of RBI and the advantages of digital elements.

The *canonical social model* by Evans & Chi illustrates the whole lifecycle of user activities of the ISS process, which is divided into three phases :

1. Before search
2. During search
3. After search

Before search The focus of the *active reading* support in the mobile context lies on individual work processes, due to the more frequent occurrence of *active reading* related activities. The phase *before search* describes the motivational factors for ISS and the user's situational context. With respect to former investigations, the researcher's individual working phases are embedded in group working processes, motivated by seminars, homework or other scientific elaborations. Thus the phase *before search* does not cover the regarded *active reading* tasks for individual working and is not further regarded.

During search The phase in which users are searching for certain objects and finally retrieve search products is covered by the phase *during search*. As this phase covers three kinds of search strategies (*informational, navigational, transactional*), the ones will be regarded, which fit the best to the scenario of identified individual work processes. The *transactional* search strategy describes a search behavior, where information seekers are very aware of a goal to achieve and information they want to reach but do not know the immediate access point. They navigate to a point of interest by using additional websites or search engines until they locate the information of interest.
The *navigational* search behavior describes the retrieval of a certain information, they were accessing earlier. They do know what they are looking for, but want to verify or just recall the search result.
Informal search behavior is an exploratory process. Information seekers do not require do be aware of a certain topic and gain an insight through sensemaking and foraging. The browsing search strategy, describes this behavior with respect to certain layers of information collections and the information objects granularity. The *informal* search, and thus *active reading* related user tasks in the ISS process is the most common one. This frequent occurrence of an informal search behavior (*browsing*) verifies the relevance of sensemaking support (*parsing*) for the user, with respect to the extraction (*selection)* of certain information artifacts.

After search After a search product was retrieved, information seekers either take action of it or refuse it. They extract additional information for later processing and require to reference the data (*selecting*), but also want to organize the excerpts for own restructuring purposes and data persistency (*operate*).

The identified work processes of visual data analysts and information seekers are now assigned to the *canonical social model* by Evans & Chi to integrate the specific individual research behavior into the entire work process of researchers (see Figure 6). This chapter discussed the regarded tasks by *active readers* with respect to the domain *library* and the mobile context. Based on these findings, adequate interaction techniques are investigated in the following. In addition to the interaction approaches, this integration process is used to be aware of requirements across a certain working process of the user's workflow.

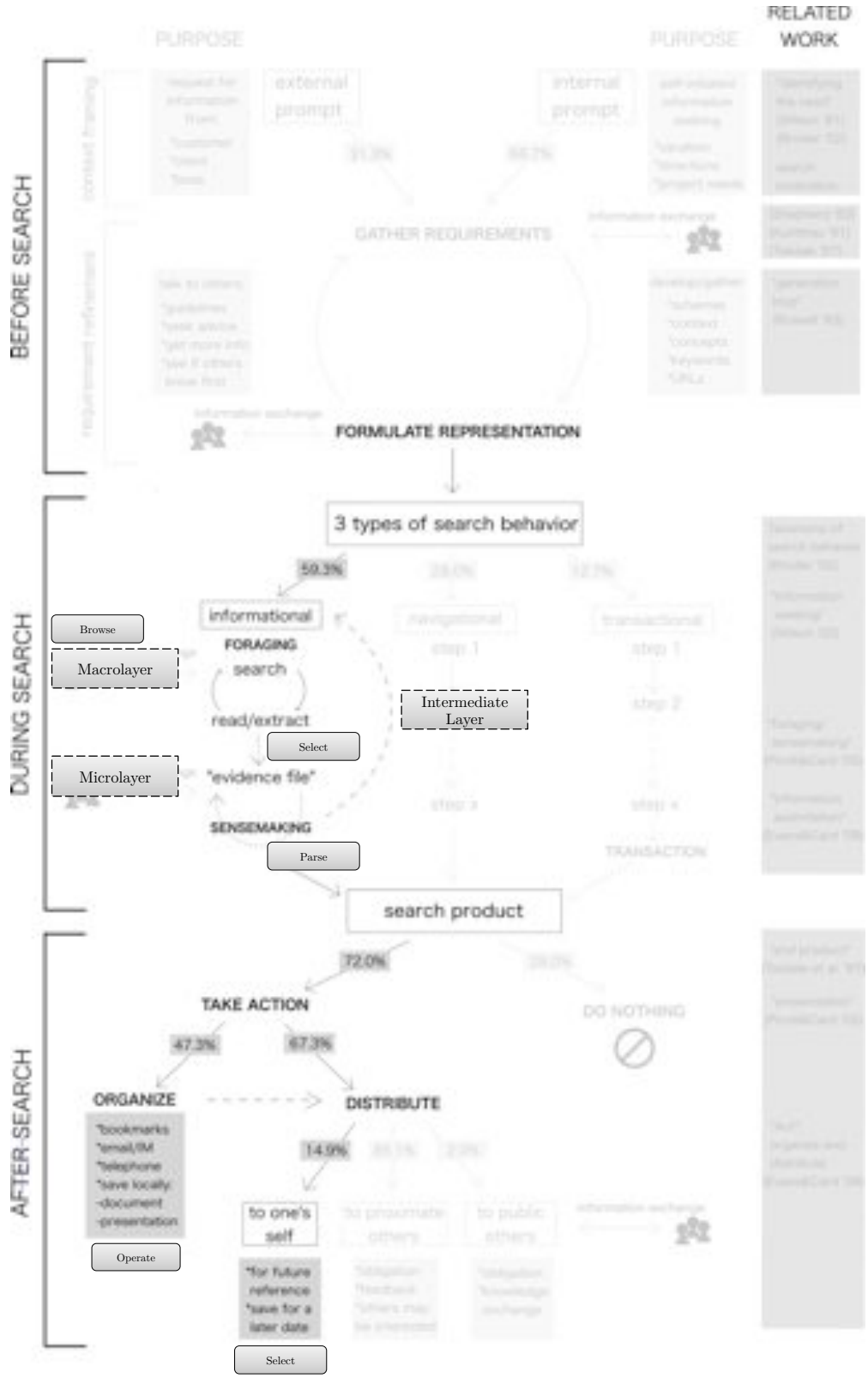


Figure 6: Specified tasks classified to the social model of user activities in information seeking and sensemaking; Dotted border elements illustrate layers of the browsing process, stroked elements represent individual work processes[14]

3.3 Requirements Analysis

As user groups of libraries have been narrowed down to researchers (*Problem Solvers & Scholars*), the user's working behavior in individual work processes and their activities have been further examined. Since scientific working is bound to information objects (whether analogue or digital), the researchers' working requirements and motivation is further determined through a requirements analysis.[6] The requirements analysis covers the identified work processes and either work methodologies and is used to investigate the required types of tools to solve individual work tasks. The insights are used to focus on main tasks and requirements in every days scientific working behavior of *active reading*, to form blends based on revealed leaks of the current operational context.
With respect to researchers' operational context, it will be distinguished between the required tools, clustered by nowadays interaction approaches. While tools as black- or whiteboards are not considered, regarded materials for *active reading* are classified as followed:

- Pen and paper
- Computers
- Tablet computers and smartphones

To form blends, different worlds and their characteristics are merged. In this case analogous - (pen and paper) and digital (computers and tablets & smartphones) world. The benefits of either world and the user's activities are examined with respect to the user's motivation to use a specific kind of tool and certain functionalities of it. In addition, the reading behavior of researchers is examined in detail. Furthermore, the reading behavior covers aspects as the reading motivation and the reason why and how additional literature is taken into consideration by the reader (*diffused* or *focussed reading*).

A systematic error of the requirements analysis due to the medium used for data collection, is avoided by using a paper-based and digital survey. Both surveys cover the same qualitative and quantitative questions. The printed sheets of paper were placed in the *Library of the University of Konstanz*, an academic library, to assure that participants are part of the target user

[6] It is known that Chen et al. have collected a list of requirements for supporting *active reading* activities, nonetheless we wanted to acquire data with respect to the specific user group of *researchers* [9].

group *researcher*. The digital survey was provided online, which was published both through a mailing list of the *University of Konstanz* and the social media website of the *Library of the University of Konstanz*.
The data evaluation among the demographical distribution of the participants and course of degree compared to the one of the *University of Konstanz* revealed that the survey is representative with respect to the students of the university (see Appendix 6.3). The student participants were also representative with respect to their degree of graduation (see Appendix 6.4). As we want to focus on a user group of a library and researchers form our target group, the investigated requirements analysis is regarded as valid fundament for a data analysis.

At first, both blended worlds (analogue and digital) and the user's corresponding behavior types were observed to get an insight into the users courses of action and to uncover certain problems, with which researchers cope. The assumption that users tend to media discontinuity by digitizing analogous media or creating an analogous copy of digital media items, was covered by 46.18% of the participants (see Appendix 6.1). Analogous information artifacts are either duplicated or summarized, while digital ones are either printed out or copied and then merged into information collections after transferring and converting the artifacts to one of either world. The caused media discontinuity with the user's intent leads to the assumption that there is need of a system, supporting researchers when working with digital and analogous information sources. The focus will lie on the support of pure digital information sources, as our requirements analysis uncovered the necessity to work with digital documents in a paper like way, which is one of the reasons, why researchers print out their digital information sources.

A further aspect to investigate is the reading behavior and the user's motivation. Based on user's reading goals Adler et al. analyzed the relative occurrence of either reading goal among work-related readers, who worked collaboratively across several work locations and were predictably mobile across several locations [1]. As Adler et al. identified the objective relevance for reading goals, based on quantitative data, as the relative frequency, the user's preferences and subjective reading goal assessment is regarded. For example, a reading goal might occur for the most of the time, still it might not be as critical for success as another one, occurring less frequent. Therefore, the requirements of the users are considered. The participants were asked to rank the different reading goals by sorting them by relevance. The rating is quantified by using a *Likert scale* from 1 (most irrelevant)

to 10 (most relevant). The most relevant reading goals are identified by the arithmetic mean 5,5, which is used as marginal value. With respect to the subjective user rating (see Figure 7), the most relevant reading goals for researchers are listed in the following with the arithmetic mean of the participant's rating:

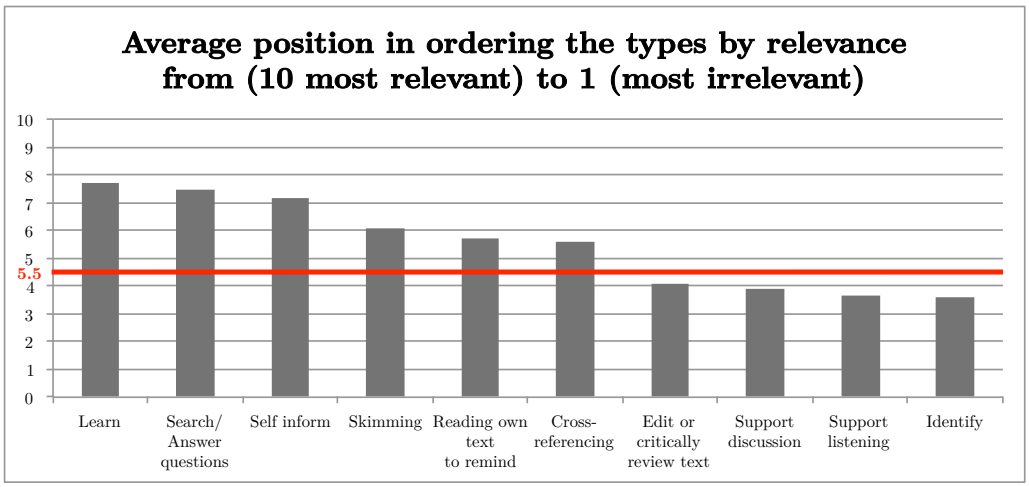


Figure 7: Requirements analysis: participants' subjective ranking with respect to ten different reading goals identified by Adler et al. [1]

1. Reading to Learn (7,824)
2. Reading to search and answer questions (7,649)
3. Reading to self inform (7,301)
4. Skimming (6,213)
5. Reading own text to remind (5,815)
6. Cross-referencing (5,767)

Nevertheless, it is assumable that results of the requirements analysis are distorted due to the timespan in which the analysis was accomplished. Most of the participants were students who started to learn for their exams and thus classified learning as most important. Compared to the point of time, when there were no exams, learning was classified as less important. Because of this inconsistency and the goal to support any researcher (not just students) when working with digital documents, the goal *reading to learn* is excluded from considered criteria and not regarded in the following.

Finally, participants were asked to comment positive and negative aspects of considered tools (pen & paper, computers, tablet computers & smartphones) they use for scientific working. The qualitative data of these statements was encoded to categories (excluding those that are affected by learning) and the absolute occurrence was quantified. Based on the quantified data, the relative frequency of each tool's categories is described (see Appendix 6) to get a list of tool independent, most important (positive) categories of researchers. The list's items are composed by the cumulative sum across the three different types of tools and the ten most frequent requirements with more than 10% of relative frequency are derived:

1. Notes, annotating (63,5%)
2. Use it anywhere, for anything (44,8 %)
3. Search (within the text as well as for further literature) (36,1%)
4. Flexible ordering (of information items) (30,7%)
5. Self-Management (23,0%)
6. Dictionaries, Thesaurus (19,3%)
7. (Multiple) Document management (15,3%)
8. (Document) Overview (13,2%)
9. Format & Export (12,3%)
10. Cross-referencing (in and between information items) (11,1%)

Regarding this classification of the ten regarded reasons for using certain tools, the aspects are considered as important requirements of researchers, which have to be regarded for scientific working support. The most frequent aspects are now assigned to the most important reading goals to make sure that each aspect is covered by the considered reading goals (see Table 11)

Reading to search and answer questions and *reading to self inform* is mainly covered by search and the opportunity to gain fast an overview of the document. With respect to the *parsing* process, dictionaries and thesauri support the reader in exploring an unknown topic or when stumbling over unknown words to search and answer questions and to self inform oneself. As skimming is performed by the reader to get a fast overview of one or multiple information objects and to reach a certain passage as fast as possible, the behavior is mainly influenced by the documents' overview and the

Reading goals		Assigned requirements
Reading to search and answer questions	←	° Search ° Dictionaries, Thesauri ° (Document) Overview
Reading to self inform	←	° (Document) Overview ° Dictionaries, Thesauri
Skimming	←	° (Document) Overview ° (Multiple) Document management
Reading own text to remind	←	° Self-Management ° Notes, annotating ° Flexible ordering
Cross-referencing	←	° (Multiple) Document management ° Cross-referencing

Table 11: Mapping of users' requirements for scientific working to reading goals. The list consolidates all requirements of pen & paper, desktop computers and mobile devices (such as smartphones and tablet computers)

multiple documents' management. To support *reading own text to remind* oneself, functionalities for self-management could be used to help the user with what to do next or which recent credential insights the reader had (flexible ordering of information items).

The mapping of the requirements (see Table 11) reveals that two requirements are not covered directly: *use it anywhere, for anything* and *format & export*. As the situational context covers already the necessity for portability and mobility support, the formatting & export aspect is covered by the embedding of the individual working process into the group work phases. As the focus lies on individual work processes, the *format & export* aspect is disregarded for further development and evaluation of interaction techniques.
Further, the requirements analysis shows the most important reading goals for researchers and the user's most important requirements with respect to physical and digital tools, used for scientific working purposes. The insight gained from the requirements analysis is now used to further investigate user's behavioral aspects and to focus their interaction traits. The requirements mapped to regarded reading goals and individual working processes are used to build a scenario for common work related tasks, which are used to form system and interaction solutions that blend physical and digital aspects, which are finally evaluated regarding their suitability and efficiency.

3.4 Related Work

In the following, software solutions will be introduced, which also have *active reading support* in focus and are partially portable. Goal of the system introduction and examination is to reveal different approaches and designs regarding the solutions. These advantages are used as inspiration for a gesture study and it's related content visualization of text documents and controls, which support *active reading* of digital documents.

Hybrid Documents

Hybrid Documents is realized on a tabletop computer environment to support knowledge workers that use a desk for paper-centric work. A desk is per se not portable and currently also not a mobile solution [13]. Nevertheless, it combines physical media items with digital features. Deininghaus et al. concluded for the user study a need of managing multiple documents and also individual approaches for note-taking and annotation purposes.

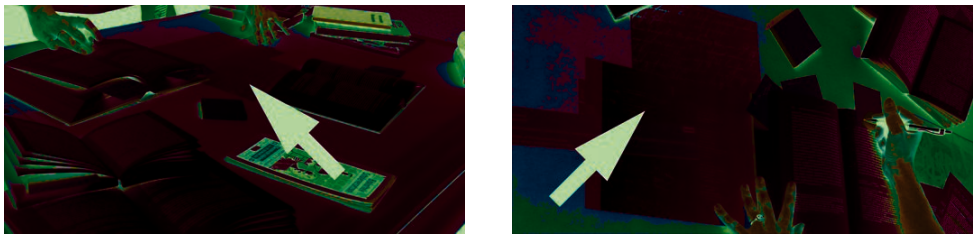


Figure 8: Introducing Hybrid Documents, arrows mark the front projection on a desk to enrich the physical world with digital information artifacts (based on [13])

Key element of the system is a physical medium, placed on the table, which is of the user's main interest (see Figure 8). Information of this specific object of interest is enriched through offering comments and annotations with digital content, projected on the table. To fasten up navigation across various documents, additional content is hyperlinked, which enables the user to access related information by simply selecting the hyperlinking. Furthermore, the blended working environment of the physical and digital world allows the user to mark certain pages as relevant, by simply extracting the pages from a book. Nonetheless, the extractions are limited to full pages and not as fine granular as *active readers* might require when excerpting

very specific terms or text abstracts.
A qualitative evaluation of the system has proven that users tend to *diffused reading* and may get confused by the depth of cross-document navigation. In addition to offering an easy to use cross-document navigation and keeping different annotation techniques and content referencing in focus, users need a visualization of their navigational path through documents.

Here, the approach by Deininghaus et al. aims to support referencing and navigation activities of knowledge workers. An evaluation proves that users require support when navigating across text passages or documents.

LiquidText

LiquidText is a tabletop computer based system, which aims to support *active reading* for knowledge workers [57]. Tashman & Edwards do not aim to mimic paper, in fact they want to avoid certain disadvantages of paper-based documents, due to physical constraints and the textual presentation, which is partitioned on a sequence of sheets of papers.
Four cornerstones are regarded to broadly support knowledge workers across all challenges they face with physical documents, based on former research [41]:[7]

Underlining / Content extraction Relevant text passages are marked, which later on shall ease understanding and recalling it's content. *LiquidText* offers users the ability to easily extract text passages to a second screen, to fasten up the reflection of extracted content.

Note-taking / Annotation Making own notes is considered as essential to facilitate text comprehension, which shall be supported by *LiquidText* with high efficiency.

Outlining / Layout For improved text comprehension, the reader is able to generate an alternative representation of text. The reader is thus supported to see text passages in parallel.

Networking / Navigation It describes navigational aspects in a certain document with respect to topic-related text passages on different positions in the document. Furthermore, this can be extended to a navigation across multiple documents.

[7] On the left side, mentioned activities, which require support, are listed by O'Hara. The right side (by Tashman & Edwards) describes the requirements more general

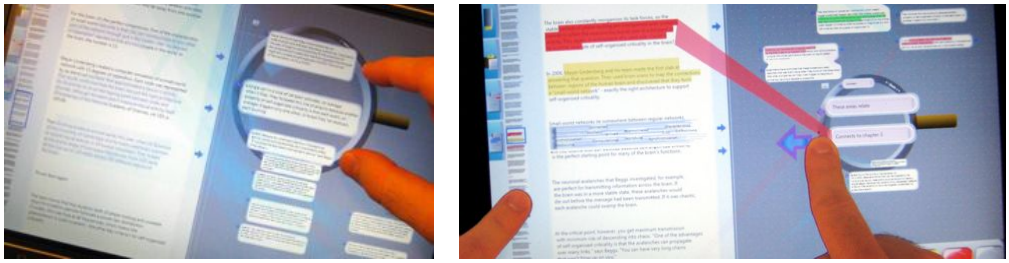


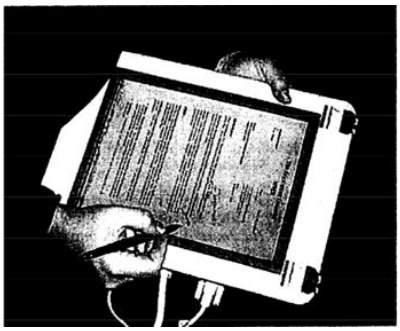
Figure 9: Introducing LiquidText. Left: Layout of the application; Right: Text extractions link back and forth to the text's origin and the extracted text object

Users are provided with two main panes. On the left side the (original) document representation and on the right side an area, where they are able to arrange extracted text fragments (see Figure 9). On the very left side is a small overview of the entire document where the current user's location is displayed to visualize the reader's progress in the current document.
As identified in the selection process, extracted text passages link back to the text's origin to easily set them in context. On the bottom right, the user is able to select a certain color with a sample board for text markings and is also able to attach dog-ears to the current document's location.

LiquidText illustrates the necessity of being able to cross-reference in an easy way, while being aware of a document's structure. Furthermore, a user is given the opportunity to extract text passages or chose between different emphasizing typologies (underlining or highlighting). Finally, the user is supported to choose between different colors for different manipulation or structuring purposes.

XLibris

XLibris runs on a tablet computer, relying on a pen-interaction technique. The visual appearance of *XLibris* aims to reproduce a paper digitally and supports reading and annotating [48]. To support the reader with background information, a list of further literature is offered, which is related to the document (see Figure 10). The list at the end of the document supports *focussed reading*, additional literature is provided, which is associated to the formerly read document.
With respect to the pen, users are enabled to use the pen for freeform annotations (circled phrases) or for simply underlining and highlighting text



Further Reading

LEGALLY SPEAKING: REGULATION OF TECHNOLOGIES TO PROTECT COPYRIGHTED WORKS. Pamela Samuelson in *Communications of the ACM*, Vol. 39, No. 7, pages 17–22; July 1996.

FORUM ON TECHNOLOGY-BASED INTELLECTUAL PROPERTY MANAGEMENT: ELECTRONIC COMMERCE FOR CONTENT. Edited by Brian Kahin and Kate Arms. Special issue of the *Interactive Multimedia News*, Vol. 2; August 1996.

LETTING LOOSE THE LIGHT: IGNITING COMMERCE IN ELECTRONIC PUBLICATION. Mark Stefik in *Internet Dreams: Archetypes, Myths, and Metaphors*. Edited by Mark Stefik. MIT Press, 1996.

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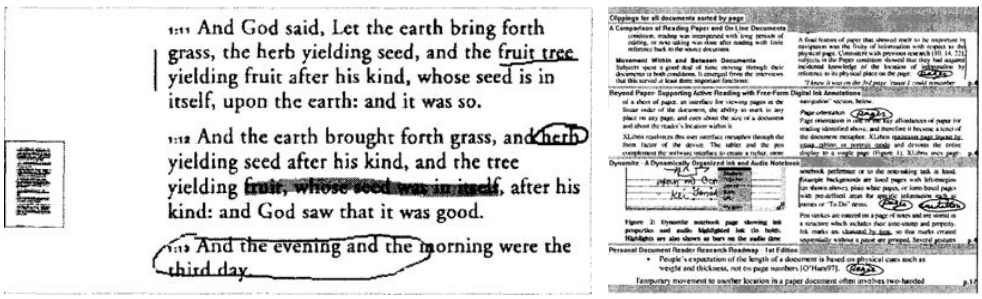
Figure 10: XLibris. Left: System setup, tablet computer and pen interaction; Right: Further reading list at the end of a document

passages [49]. Furthermore, the reader is able to use free-form ink for annotating and is additionally offered a blank notebook, where notes could be left (see Figure 10). Based on annotations and the selected text passage's content and domain, additional relevant reading recommendations are given. This specific reading list is generated and manipulated by the user's input, as it reacts on selected text passages and used terms. Just as the reading list of the end of the document, these results are displayed in a separate view, which could be accessed at any time, so *diffused reading* is indirectly offered as well.



1:11 And God said, Let the earth bring forth grass, the herb yielding seed, and the fruit tree yielding fruit after his kind, whose seed is in itself, upon the earth: and it was so.

1:12 And the earth brought forth grass, and herb yielding seed after his kind, and the tree yielding fruit, whose seed was in itself, after his kind: and God saw that it was good.

1:13 And the evening and the morning were the third day.

Figure 11: Pen interaction approach of XLibris. Left: Different marking modes, underlining, free-form ink and highlighting; Right: Further reading list, associated with selected text passage's content

An evaluation of *XLibris* among knowledge workers has verified the suitability of this interaction technique, because it eases *active reading* tasks with digital documents. When developing an interaction approach, which is suitable for *active reading* of digital documents in the mobile context, similarly approaches shall help to identify appropriate interaction techniques for a *blended interaction.*

iBooks

iBooks is a proprietary system, which is available for the *Apple iPad*. The software is running on a tablet computer and used by touch input. Users are offered different approaches to navigate through a document (by tap or swipe gestures) and are given several functionalities, which support *active reading tasks*. Furthermore, the content is not limited to text elements, in fact it offers interactive surveys, images and videos embedded in the text.

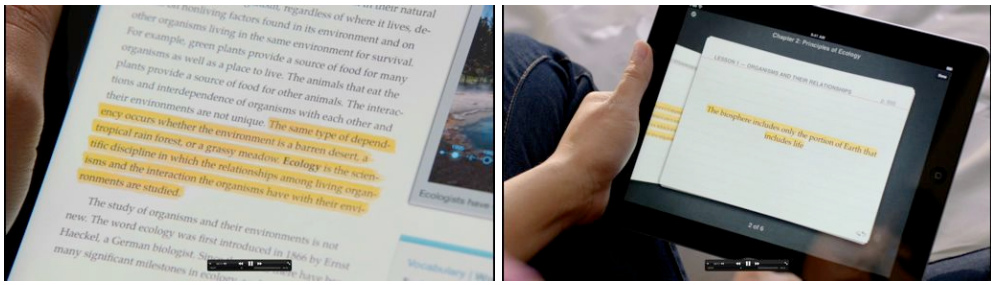


Figure 12: iBooks. Left: highlighted text passages of an object of interest; Right: index cards displaying selected text parts and related annotations made by the user

Users are able to underline and highlight text with different colors. These selected text passages can then be annotated and be seen in an extra view where all text extractions and related comments are displayed as index cards (see Figure 12).
Unknown words and terms can easily be looked up in an integrated glossary, which explains the terms with making use of different media types. Regarding the overall content visualization, *iBooks* mostly makes use of the paper metaphor, goal of the visualization is to display content in an appropriate way, while keeping a chapter and page structure through which a user shall be easily be able to navigate through.

Projected Augmented Books

In 2011, a concept of using a physical book enriched with digital content was given by Dachselt & AL-Saiegh [11]. The idea bases on the approach to enhance physical tools (a pen for highlighting, for example) and active reading tasks (such as highlighting and underlining) with digital elements, while keeping a natural way of user interaction. These target group are students or knowledge workers, who can also use this kind of technology in the mobile context, because just a lamp or pico projector is required.

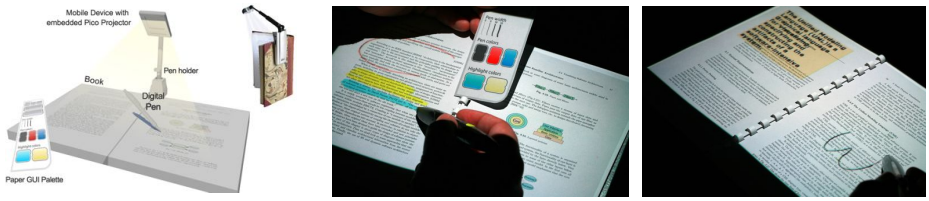


Figure 13: Projected Augmented Books. Left: technology setup, a pico projector attached to a physical book; Right: interaction approach and visualization of digital elements on top of the book's surface

The pico projector is attached to a physical book to visualize additional digital information on top of the book (see Figure 13). An *Anoto*[8] *pen* is then used to interact with these elements. The goal of this concept is to integrate the work process in the user's context. A reader shall be able to share information with friends and to access third party websites and dictionaries.
The active reading tasks are limited to common text modification tasks, such as emphases and copy & paste. The user is given the opportunity to emphasize text in a well-known way and is able to encircle or simply highlight text passages with the pen. In addition to the encircling, users can perform pen gestures like a c for copying or x for deleting an annotation.

Findings of Dachselt & AL-Saiegh show that the gesture strokes really have to be reliable for user's but are considered as helpful. Furthermore an interactive palette supports user's to switch between certain (color) states of the *active reading* process. Although the setup is not yet truely mobile and has to be improved, a further challenge is the aspect of providing books with the on printed Anoto pattern to support the interaction approach on physical books.

[8] http://www.anoto.com/, seen July 2012

4 Interaction Design

With respect to the user's requirements and situational context, a supportive software for *active reading* in the mobile context aims to provide an adequate interaction design that fits to the operational context of the readers. Hence users work processes have been examined in detail, the user's concrete behavior and requirements for operating will be acquired in the following to create a model that fits best to the operational needs:

> "The operational context can have an impact on the relative importance of various design objectives, such as speed of operation, ease of learning, and the like,[!sic] and on highly specific design decisions and details, such as the use of sound or the placement of controls."
>
> *Constantine, Larry L. & Lockwood, Lucy A. D.* [10:299]

The end users shall be enabled to use the (software) solution with a high fitness for purpose and ergonomics of human-computer interaction. This includes effectiveness, efficiency and satisfaction in a particular context of use [27:4]. Constantine & Lockwood emphasize the relevancy for context information for a certain use case and refer to a list of profiles[9] to focus on to provide an effective, efficient and error-free problem solution [10]:

- **Incumbents** Characteristics of the given users who will play a given role
- **Proficiency** How usage proficiency is distributed over time and among users in a given role
- **Interaction** Characteristic patterns of usage associated with a given role, use case, or set of use cases

[9] Because this is no production system, integrated into every days workflows of researchers, those profiles are taken into consideration, which are relevant to focus on for the investigation of interaction techniques and cover user requirements.

- **Device constraints** Limitations or constraining characteristics of the physical equipment
- **Environment** Relevant factors of the physical environment
- **Functional support** Specific functions, features, or facilities needed to support users in a given role or for specific use case or set of use cases
- **Usability criteria** Specific functions, features, or facilities needed to support users in a given role or for a specific use case or set of use cases

Incumbents Former specifications have isolated the target users as *researchers*. In contrast to domains of the university, where also academical courses are offered, the focus lies on research and it's individual working processes only. Revision purposes by second - or third authors and derived correction purposes are not main part of this elaboration, but may be partly covered by offered functionalities.

Proficiency Pen & paper is a well known medium by researchers. Nonetheless, certain abilities and working traits are adopted by the user over time. For example, accessing referenced literature as efficient as possible through third party digital libraries or conventional libraries. Unlike pen & paper, tablet computers have recently been introduced and are not well-known throughout the entire user group. People start to get aware of how to interact with this kind of hardware. In the upcoming years, this technology will be even more established, as users grow up with this technology and got into touch with it from the early childhood on. Thus, it is focussed on those that are already aware of touch interaction technology, but maybe new to scientific working on tablet computers.

Interaction The individual working process is embedded constantly in the overall group work activities, confirmed by Evans & Chi through the canonical social model of user activities in ISS (see Figure 6). While reading affects a researcher in every days work processes among different situational contexts, the results have to be accessible and integrated. For example, a user is up for a group work appointment, writes down relevant documents for further processing and wants to access and work with these documents on the way back home. This implicit data integration should be covered, when offering a software solution for scientific working on tablet computers.

Device constraints & Environment With disregard to the battery time[10] and readability weaknesses of most tablet computers' displays in sunlight, the focus of this work is the mobile context. With respect to this operational context, user thus require a portable device and portable documents. While a vast amount of printed documents is getting a user into trouble, due to physical properties (size, weight and bend-prone paper sheets), the digital properties solve those issues with a certain amount of storage, a display and the opportunity to switch between documents and of course work-related tasks (e.g. open an e-mail related to an elaboration).

Functional support & Usability criteria Functions and features that support users with respect to usability goals rely on the users' requirements in the given domain of researchers and their scientific working tasks in the individual working processes. Functional support and usability criteria is thus dependent on the set use cases, which will be described in the following chapters.

4.1 Preliminary Gesture Study

Based on common usage scenarios throughout the data analysis and mentioned requirements, a gesture study is conducted to investigate how researchers would interact with digital media on a tablet device. The performed gestures are used to further investigate a gestures set of most relevant interaction techniques for active reading.

With respect to the investigated tablet computer setup, the study is used to find out what kinds of tools are used and how often researchers make use of them. Because used tools that are taken into account for *active reading* shall be identified, users are not restricted to one single tool. The participants were instructed not to limit their ideas and concepts by technical constraints and were offered with a bunch of tools. Although the offering of different tools might overstrain users with a lot of different mechanisms, users create the mechanisms on their own. Thus, users rate in a second step their interaction approach to solve a task with respect to their grade of satisfaction and consistency, based on questions of a gesture study accomplished by Heydekorn et al. [22].

While former studies of electronic reading solutions have evaluated their concepts and ideas of interaction techniques ex post, we want to build up

[10] http://www.apple.com/batteries/ipad.html, seen March 2013

the gesture set ex ante. For example, users want to look up the meaning of an unknown term, but what kind of interaction technique do they use to trigger a specific function and does the technique stay in conflict to other functionalities? Those that rely on real world (such as pens or fingers) interaction techniques take advantage of well-known physical traits, especially pens and fingers are considered as highly relevant for *active reading* and the focus lies on these tools in the gesture study [26]. The tasks to solve derive from mentioned key requirements of our target user group (see Table 11), the defined operational mobile context and the regarded individual work processes:

- Browse
- Parse
- Select
- Operate

Each task was performed with respect to four questions to gain additional insight in the user's expectations regarding a system, supporting scientific working with a tablet computer. The following questions aim to get additional insight in the user's expectations. Although users were asked to think aloud, certain additional aspects might being disregarded, if the user was not explicitly asked about it, once again at the end of the task:

- How is the user interacting
- Which result is expected by the user
- Where are the results expected by the user (tablet computer, wall display, position)
- What would the user have expected or required

General

Five researchers were recruited to take part in the study. In average they were 26 years old, ranging from 22 to 31. All participants are right-handed and experienced in using touch devices. To animate the users to use common physical traits on a hardware setting, which is used to support digital content, a paper prototype of a tablet computer and it's content is used [18]. Subjects are free to use touch or pen interaction or a combination of both (*multimodal* [38, 57]) with either one or two hand (*multi manual*

[38, 42]). Due to the paper based approach, participants are able to draw required elements on the sheet of paper for a better conceptualization of a required graphical interface.

Browse

Articles found by browsed looking tend to be significantly more interesting for the users, although they prefer search tools to locate an information object of interest [59]. Search tools and search engines are already a substantial part of a library's infrastructure. Nevertheless, the aspect to support readers with related objects (whether terms or referenced literature) to their current document of interest is an essential need for supporting the browsing behavior.
As whiteboards and chalkboards are well-known by researchers, the participants also had the opportunity to use a whiteboard as large information environment, whether for background information or for exploring a large information space. This large information space represents the *macro layer*, where a collection could be presented. Due to physical constraints, the whiteboard would be located on static workplaces, which offer the infrastructure and the system would be restricted to the tablet computer in the mobile context. Nonetheless, the participants were offered this functionality, to not constrain them. The *micro layer* is represented by the display of a tablet computer, where the scientist is able to examine an information object in detail. Here, the user was asked to require additional information regarding an unknown term and requesting a referenced literature to simulate the *intermediate layer*. To not overstrain the participant with distracting text elements, just text passages that are relevant for the task were illustrated on the paper prototype (see Figure 14).

Beside the visual representation of the rudimentary user interface, the user behavior for an unknown term is also regarded as relevant for a text search, as query based text searches are better rated than full-text search or common browsing [48]. While most of the interaction was performed through touch on the tablet computer, the information space exploration was mostly held at the wall display. Most of the users interacted at the whiteboard to organize and retrieve information objects in (drawn) clusters. Nevertheless, a participant mentioned to prefer not to switch between a tablet computer and a wall, because the user wants to stick to the current setup and would rather be irritated by changing the focus.

Figure 14: Preliminary Gesture Study – Browsing; task to select a word for background information and request and open a referenced document

Although the whiteboard, representing a wall display, was attractive for exploring large information spaces, the physical constraints of the mobile context limit the transferability of a common workplace to fluctuating places in the public. Thus, the focus lies on an interaction approach with tablet computers (see Figure 15). Based on the results, the browsing process is mainly triggered by touch interaction, as users mostly tapped on words or text passages of their interest.

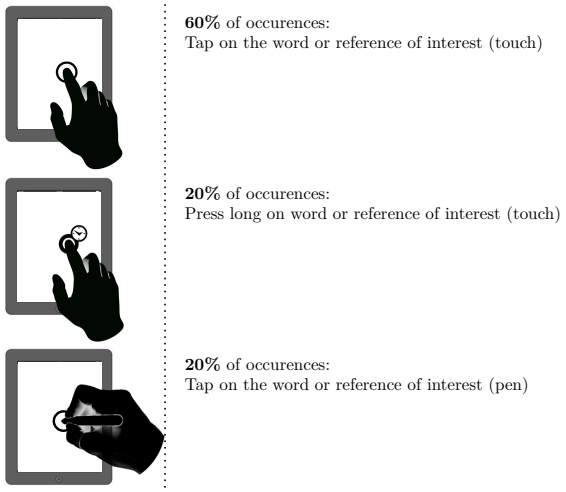


Figure 15: Preliminary Gesture Study – Browsing; performed gestures by the participants

This insight is also confirmed by the rating of the utility of either input modality (finger/touch and pen) with respect to the tasks to solve for *browsing* (see Figure 16). While the solution approach was recreated due to the evolutionary complexity of the tasks, most of the tasks were solved by touch interaction, which led most users to rate the pen as unnecessary.

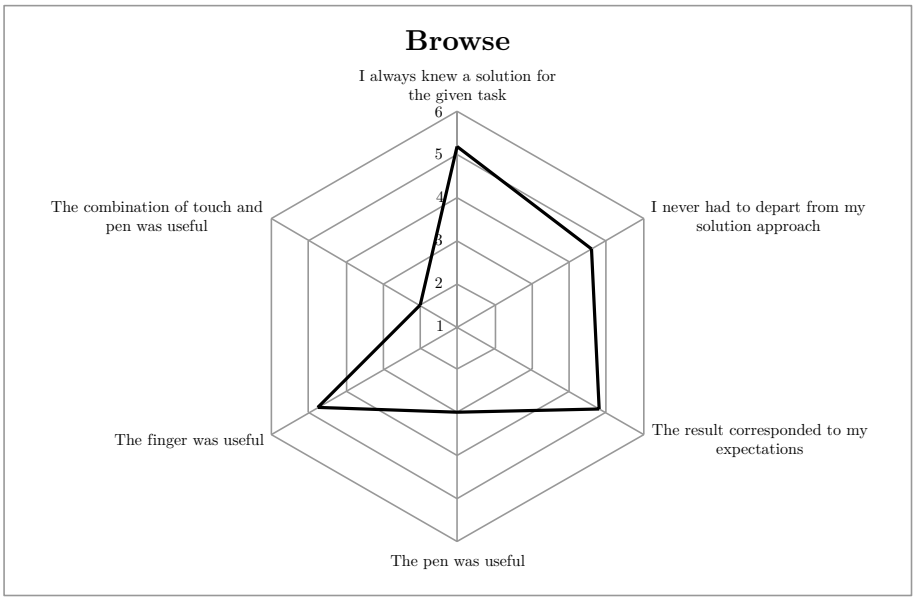


Figure 16: Preliminary Gesture Study – Browse; participant's rating regarding the individual approach of task solving

Parse

Different aspects for parsing are taken into consideration, as the *parsing* is regarded to offer text comprehension support:

Integrate dictionaries and thesauri [63]
For comprehension purposes of unknown terms or words, readers require to access background information, this behavior is merged with the requirement of serendipitous browsing by accessing immediately referenced literature, the reader might come across with in a document of interest.

Display more pages side by side [38]
Furthermore, the ability to compare information from different locations of interest with each other to make sense of text passages or

interpret data is necessary. Former text passages might define terms or explain issues, which prompt users to access different information artifacts of one or multiple document's passages [40].

Look for trends and correlations [40]
For understanding a domain or topic, content correlations are indispensable for getting an insight. Thus not only the assessment of correlated information objects is regarded in the *browsing* process, but also the opportunity of referencing marked passages with each other for *operating* with these information artifacts in the following processes.

Proofing & Skimming [5]
As the document's relevance is estimated on the macro layer of the *browsing* process, readers still require to fast check the content of a document they once took into consideration,. Motivated by retrieving a former text passage of interest, which is with regard to its content related to another text passage's content.

Cross-referencing [63]
Correlated document's content, text passages or annotations, simply information artifacts, might belong to each other for better understanding. For a steady linking of these passages, user refer from these artifacts to another. If they come across these passages once again, readers will immediately perceive the referenced information artifact, which might help to make sense of a specific conclusion.

Re-Read sections for understanding [42]
Re-reading is motivated by different facts. For example, confirmation of gained insight is needed by the reader or the reader still requires clarifying certain aspects for better understanding. In either way, former text passages (also from former documents) have to be retrieved easily. Especially, for *diffused reading* support, readers have to easily be able to retrieve their original location of interest.

Searching [63]
Search functionalities are versatile. The topic might be classified in the *browsing* process, but readers also require to look for related words in current documents or in their entire library.

Regarding O'Hara and Sellen, readers require "independent reading and writing spaces [sic!] which could be accessed concurrently and manipulated independently"[42]. The reader thus shall be offered an annotation area,

comparable to a separate notebook, where annotations and references are represented. The area is displayed to the left or right of a document of interest and may be manipulated with respect to it's width, in case the reader requires to display two documents side by side. The references may take place between or within certain document's passages or annotations. The purpose of inspecting the reference behavior is thus to identify the most common interaction technique, performed by the readers, and the location where they perform certain actions (see Figure 17).

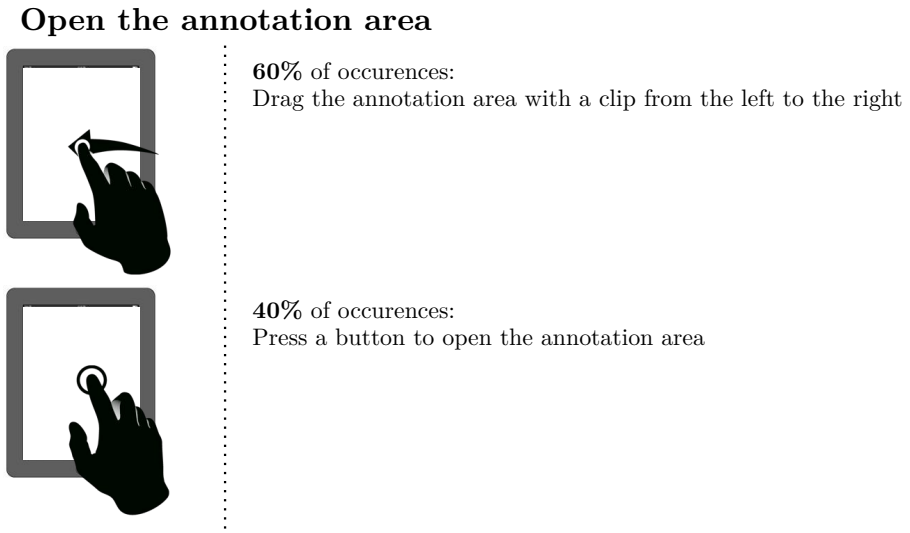
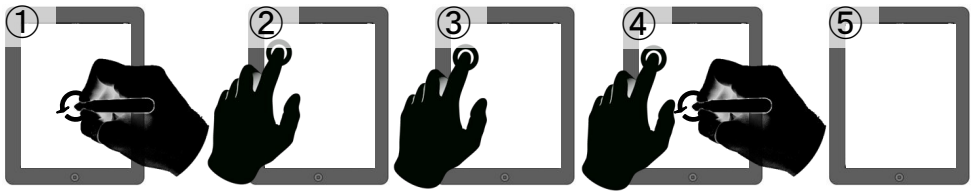


Figure 17: Preliminary Gesture Study – Parsing; arrange an annotation area

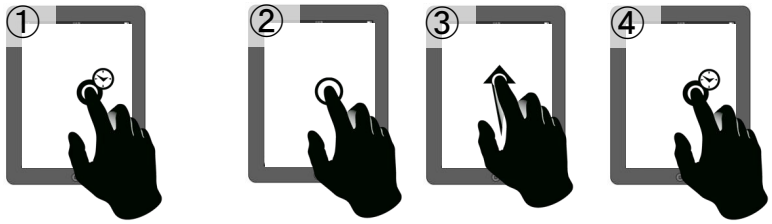
After opening the *annotation area*, the researchers were asked to reference information artifacts of interest (see Figure 18). As the *selection* process was examined later on in detail, selected text passages were offered to the participants. Two participants were willing to work with a secondary click, as they know it from their desktop computer. The secondary click (right click on their desktop computer) was performed by long pressing on the area of interest and a context menu would appear, where additional manipulation options could be selected or were selected by default.
Most people performed in a more complex but more time efficient way, by using both hands and both tools - pen and touch. The information artifact of interest is selected with the pen (here with an elliptic shape). Afterwards, the mode is switched to *referencing* through touching a toggle button. The navigation was performed on the same way and the selection was performed as before, drawing an elliptic shape in or around the information artifact of

interest, which shall be referenced. Finally, the toggle button for referencing is released and the references are established.

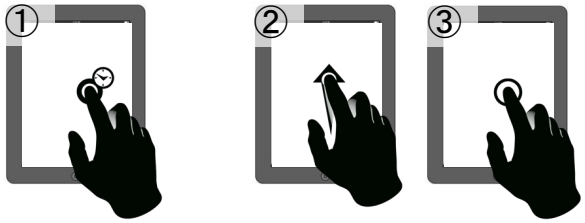
Cross-referencing *words, sentences, abstracts*



60% of occurences:
① Select an information artifact
② Switch mode to *referencing*
③ Navigate to the other location of interest
④ Select the other information artifact
⑤ Release *referencing* mode



20% of occurences:
① Open context menu by long pressing on a selection of an information artifact
② Switch mode to *referencing*
③ Navigate to the other location of interest
④ Select the other information artifact



20% of occurences:
① Create reference by long pressing on a selection of an information artifact
② Navigate to the other location of interest
③ Select the other information artifact

Figure 18: Preliminary Gesture Study – Parsing; gestures performed by participants for cross-referencing between or within certain document's passages or annotations

In general the participants had to rethink about their solutions. The initial referencing task was accomplished within a certain document. Their approach for solving the referencing across documents or between annotations and text passages of interest was modified, until the presented solutions were finally found and consistent. In comparison to the process of /browsing, the pen's utility was ranked higher and thus more necessary for the parsing process (see Figure 19). This attributes to the approach of activating an annotation or text passage of interest.

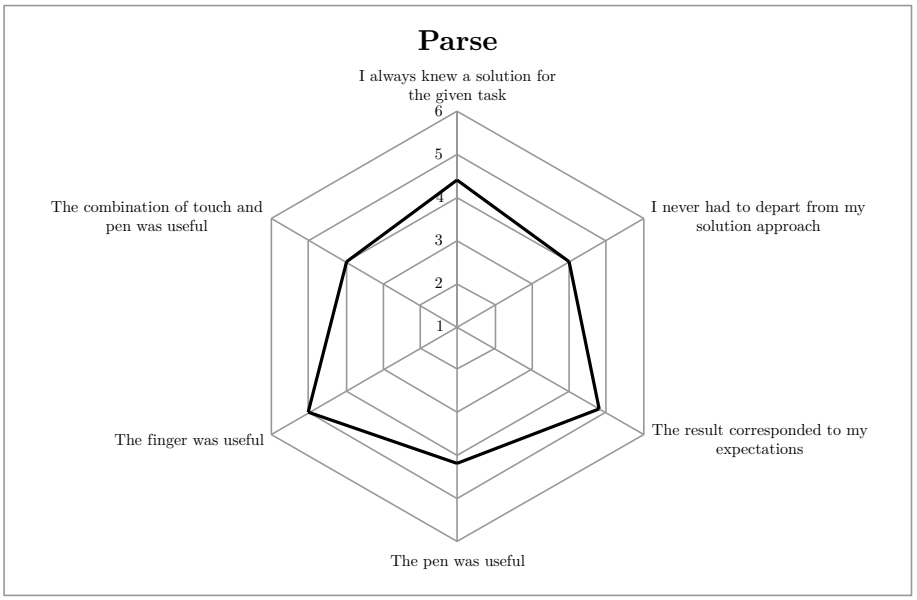


Figure 19: Preliminary Gesture Study – Parsing; participant's rating regarding the individual approach of task solving

In addition, participants mentioned further requirements, which are partly regarded in the final implementation of a system as the functionalities complement the interaction findings for referencing[11]:

Scaling of the *annotation area*

As the document's width is manipulatable, users requested to modify the width of the annotations, for example, to just write down annotations, as they are used to it in a notebook. In case the *annotations' area* would require the whole display, the document was not visible

[11] An exception is the *implicit linking*. This is a separate feature, based on text analysis and text processing, which is not regarded by the author. Nevertheless, it is listed for the sake of completeness.

anymore. In such case, simple highlightings or underlinings would not be visible in the *annotation's area*, since they are part of the document itself. Therefore, a participant mentioned that highlightings or formfillings would then be integrated as note, which references as quote to the original document, in the *annotation area*. Furthermore, the annotations and their preview would be scaled small, if the size of the area is decreased by the user.

Direct linking
A user perceived as very comfortable, if information artifacts and annotations were directly linkable through drawing a line with the pen between both objects of interest. Unfortunately, this requires for both objects to be located close to each other, due to the screens limitations.

Implicit linking
In addition to direct linking, which eases the referencing activity, a user mentioned to automatically reference terms, descriptions or passages by using certain keywords as "*see* chapter 13".

The amount of functionalities to offer an adequate interaction behavior is limited to the ones, which are related the most to rather complex interaction techniques. This is why, *dictionaries and thesauri* are as a first step disregarded. Other aspects are taken indirectly into account. For example *proofing & skimming* is seen as part of *cross-referencing* or a search functionality.

Select

The information selection process may be established across certain layers. On the one hand whole documents are either classified as relevant or not, and a user thus requires the opportunity to fast estimate the relevance of a document, which the reader parsed formerly. On the other hand, information artifacts have to be selected, which are taken into account when estimating the overall relevance of a document to identify a "critical subset of relevant or unique items"[40]. The need of a selection mainly occurs, when parsing a document, while the overall document selection is rather used as post processing. To support these activities, former research has revealed the following aspects:

Multiple ways of annotating
In addition to the identified content selection approaches in chapter

3.2, *active readers* also require to reference to multiple selected or highlighted text passages in one comment and furthermore require to color code their annotations [57].

Bookmarks

Paper provides a reader with opportunities as *dog-ears* or bookmarks, which fasten up the retrieval of recent or important text passages. Especially, for self-management purposes, users can easily track their current progress in the document and pick up a former work process, which was interrupted [63].

Compare data

Comparison purposes of different data sources motivate the user for accessing several documents simultaneously and navigate back and forth through the cross-documents' navigation stack to make comparisons [38].

Interacting with selected information artifacts

Selecting relevant information chunks from a document's content is not sufficient enough, as readers require to cluster their findings and arrange them with respect to their individual mental model and to also link from selected and annotated information artifacts back to their origin to catch their context once again [40]. Furthermore, it is considered as helpful to allow users to navigate from one annotation or selection to another one, which could be established in a separate area [42].

Different aggregates or scalings

For better conceptualization, readers require from time to time to fan out their document or to change it's visual appearance [42]. Readers require to manipulate the information representation for better readability. Reformatting or scaling changes the visualization and might support the user to better compare objects with each other [40].

The focus of the user evaluation lies on the selection of information artifacts. Users are asked to select words, sentences, abstracts and also annotate text passages. Additional aspects taken into account are how users change their current color selection or switch between certain modes, as they want to write and highlight text passages with one single pen.
The participants were given a text on a sheet of paper, which was clipped into the paper tablet computer, where different selection strategies had to be solved and finally some selected information artifacts were deselected

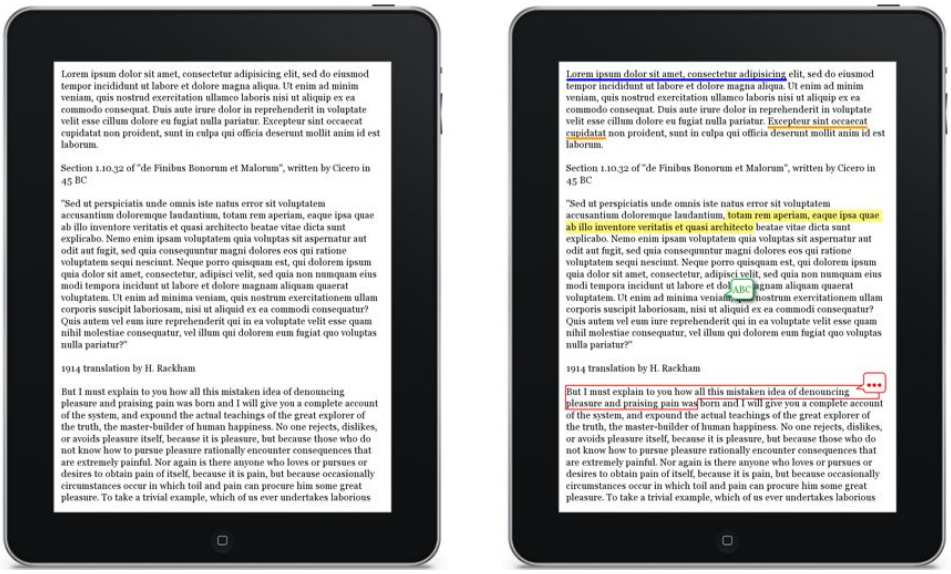


Figure 20: Preliminary Gesture Study – Selection; task to select text parts for annotation and highlighting purposes. Left: original document's appearance; Right: goal to be reached by the participants interaction approaches

again (see Figure 20).
While the visual appearance of the resulting state is straight forward (either highlighted, underlined or framed passages), the approaches by the participants differed. As physical interaction with paper documents seems to animate users to develop easier and faster selection strategies, they transfer these strategies now to the paper like tablet computer setting of the user study. In addition to the common highlight or underline approach, where the whole text passages were treated, different selection modes in combination with gestures were introduced. As almost all[12] selection strategies were performed with the pen, across all participants, the interaction approaches for selection will be described in the following with respect to pen interaction.
The *greedy approach* of some participants is to interact with the paperlike system as they would do with different markers or tools on paper. For example, they simply underline the text, they want to underline, although the strokes are not accurate and participants have difficulties to hit the space between two lines on the paper based tablet. For highlighting, some users simply strike text parts through, which was for other participants no choice.

[12] One participant refused to interact with a pen on a tablet computer, but solved the selection tasks with the pen.

They do not want to strike text passages out but rather emphasize it. Nevertheless, the participants developed alternative strategies for emphasizing text parts (see Figure 21), as they noticed that some techniques are rather uncomfortable to use.

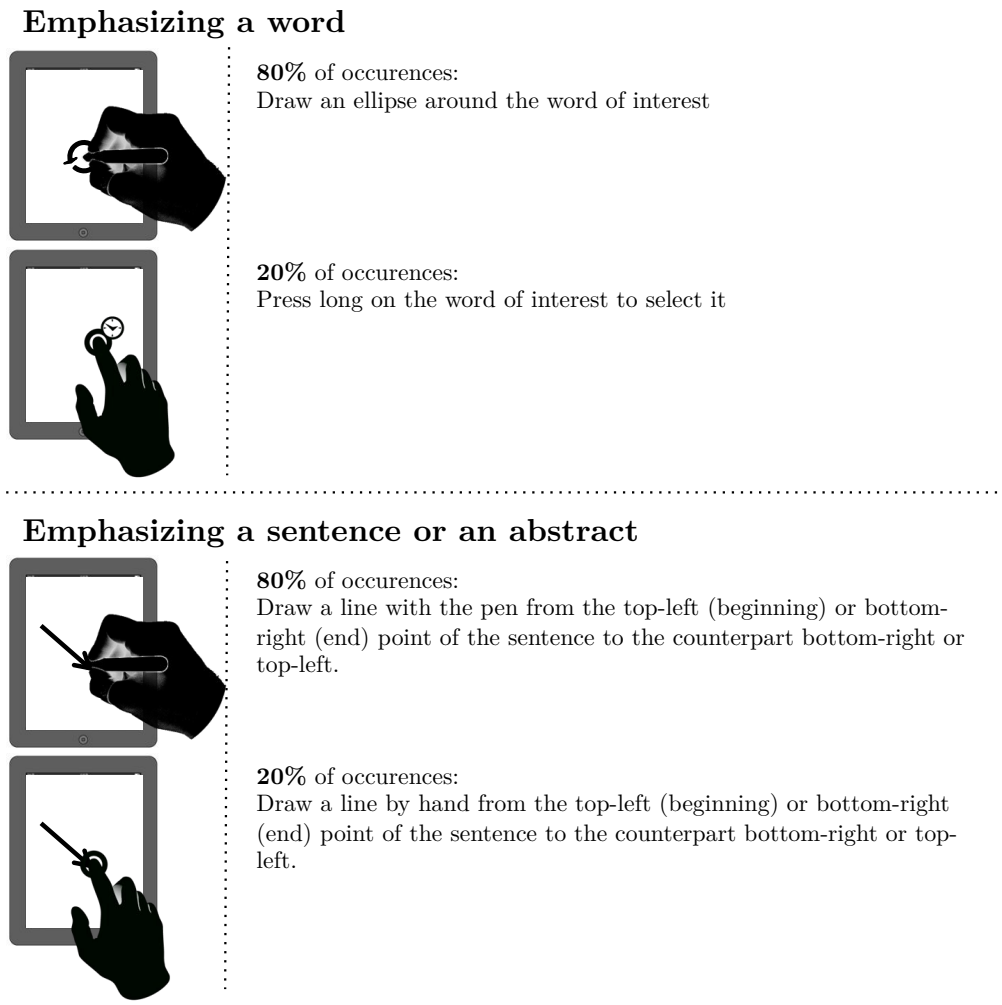


Figure 21: Preliminary Gesture Study – Selection; Approaches for emphasizing a word, sentence or an abstract

These *lazy approaches* are interaction techniques, the users either could imagine to use on digital documents or they really use when working with physical documents. The approaches are mainly executed with pen gestures and classified as followed:

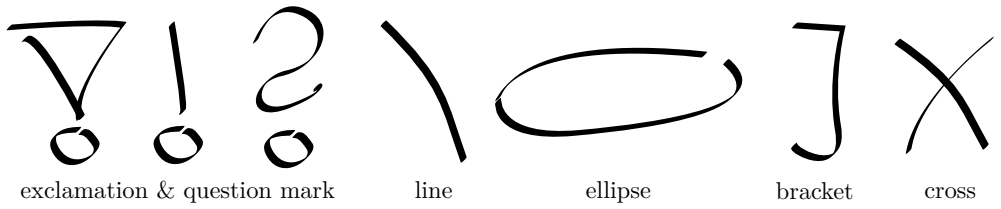


Figure 22: Preliminary Gesture Study – Selection; lazy interaction approaches for text (de-)selection purposes

- **exclamation mark** parts of the text are considered as important
- **question mark** parts of the text are incomprehensible and require further investigation
- **ellipse, bracket and line** mark important text passages
- **cross** delete annotations or deselect emphases

In addition to the emphasizing pen strokes, the participants also mentioned to require the following functions:

Handwritten annotations
: Most users preferred handwritten strokes for annotating than computer fonts and onscreen keyboard input, because it was more personalized for them.

Symbol area
: Paper offers the advantage to have space on the outer surface of the text. A participant desired to have a certain area, where easily symbols or signs could be drawn, such as the formerly identified question mark or exclamation mark.

Color selection
: As the participants were given just one single pen to solve emphasizing with different colors, they had to investigate a solution to change the color on their most preferred way. Across all participants, there was a consensus with respect of the interface. All participants expected a kind of sample board, where they could change the color mode.

Intuitive deselection

For deselecting a certain annotation or highlighting, different approaches occurred. One approach was to select a selected text passage once again: "minus times minus equals plus"[13]. Another approach was to strike through single lines of underlining with serpentine lines. The most common and intuitive approach for deselecting an emphasis was considered by creating the *clear color mode*, where colored emphases are simply cleared when selected.

In comparison to the other processes, the pen's utility is rated the highest with respect to the touch interaction (see Figure 23). Further evidence of it's ease of use is the behavior of a participant, who mentioned not to be willing to interact with a pen on a tablet computer, but solved all tasks with the pen. Nonetheless, the combination of both modalities is rather considered as less useful, as users used pen - and touch interaction not simultaneously but rather in sequence.

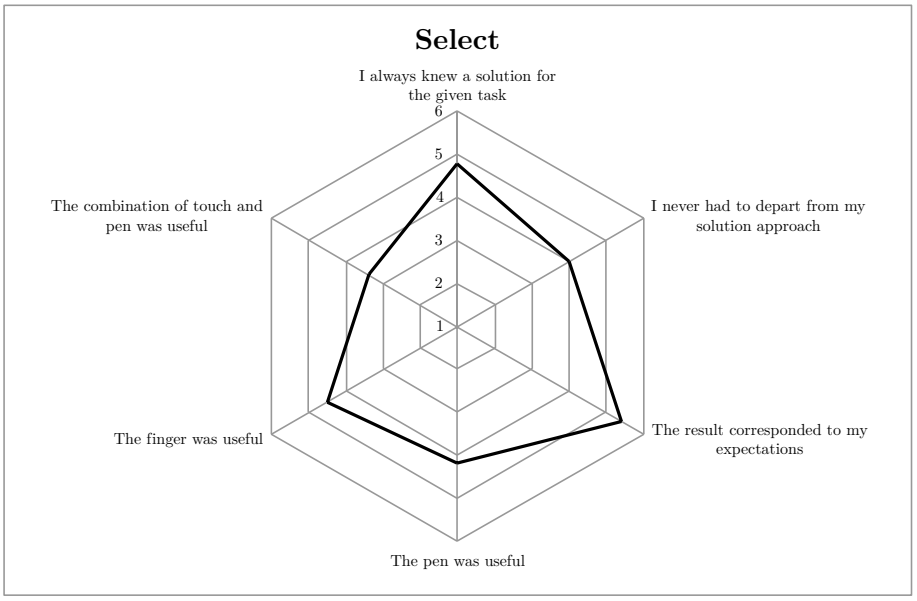


Figure 23: Preliminary Gesture Study – Selection; participant's rating regarding the individual approach of task solving

[13] Quote of a participant. Original quote: "Minus mal minus ergibt plus." [Translation was done by the author, T. B.]

Operate

After the information artifact acquisition, participants are asked to work with selected information artifacts. Making sense out of their information subset, set it's artifacts into context and constructing new schemata requires to interact with the artifacts in a convenient way. Furthermore, the insights need to be shared with other group members, as the individual working process is just part of the overall scientific working approach [1, 57]. Although mentioned as necessary for operation purposes, the following aspects are not regarded in the user study:[14]

Writing Users generate new insights and knowledge based on a variety of data sources. After fusing different sources, the selected items are linked with each other and set into context. For content generation purposes, the device should support writing, even while another document is opened [1, 42]. In addition, text composition requires text manipulation support for copied text (marked as such) and text areas where a user could write text in and make own annotations [42].

Spell-checking
The knowledge generation based on text writing also requires to be as correct as possible. Morris et al. thus recommend spell-checking for generated text elements [38]. As spell-checking is a well-known feature for text processing environments.

The operating procedures covered mainly the rearrangement of information artifacts, documents or any other kind of media object. Subjects are asked to cluster, move and also delete certain objects on a given area where the items are positioned (see Figure 24). The entities are positioned in a blank area, where there is no additional text document displayed or opened to not distract participants. In fact, this area could be considered as notebook, where information artifacts and selected documents are clipped. This notebook could serve as kind of extension of the annotation area, where the final operating and editing of a pre-mental model could be established.
The task does not distinguish between certain information artifacts generated from text passages, copied quotes or entire documents. The objective

[14] The focus lies on *active reading* and a resulting multimodal and bimanual interaction approach on tablet computers. Goal of the preliminary gesture study is the generation of a set of gestures, which cover the main operational methods by researchers' *active reading* behavior. Although text processing is part of the operating process, it is not considered as highly relevant for the *active reading* focus. Goal is not to implement a text editor, but rather a system supporting *active reading* to make sense of a document's content to set this insight into context.

of these tasks is to generate a consistent interaction approach with disregard of a very specific media item but rather to provide a generic approach, valid for any manipulatable object.

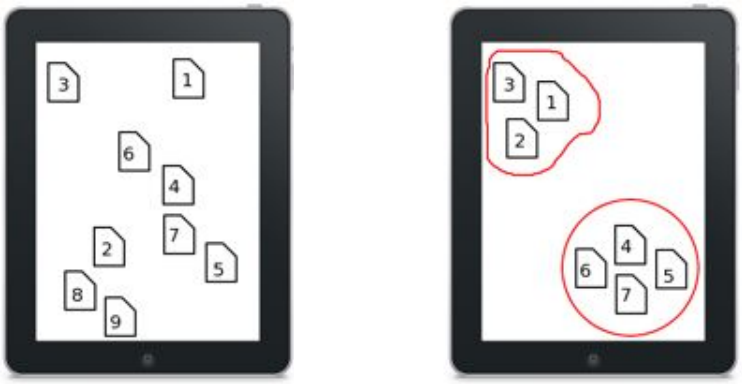


Figure 24: Preliminary Gesture Study – Operating; task to rearrange a bunch of given information artifacts. Left: original positioning of a set of information artifacts; Right: goal to achieve through manipulating user interactions

While Tashman & Edwards state that tablet computers are not sufficient enough to see all documents, all participants refused to operate on the wall or any other facility and stuck to the tablet computer [57]. Participants rather preferred a (zoomable) landscape, where they could navigate and rearrange information artifacts. Whether this kind of visualization and interaction is scalable to a vast amount of several 100 documents is arguable, as the study just covers nine objects to catch basic courses of action for a simple and consistent interaction approach.
The interaction movements and executions are to the greatest possible extend equal among all participants, excluding the modality the users used to solve the task. Beside one subject, all other participants were drawing a shape around objects, they wanted to cluster or select for further processing (see Figure 25). Some subjects mentioned to require a separate mode for information artifact manipulation. For activating this specific manipulation mode, they pressed long on the surface or information artifact and then were able to rearrange, delete or cluster the objects. Nevertheless, the resulting gestures in this specific manipulation mode were (with disregard to the modality) equal to the others.

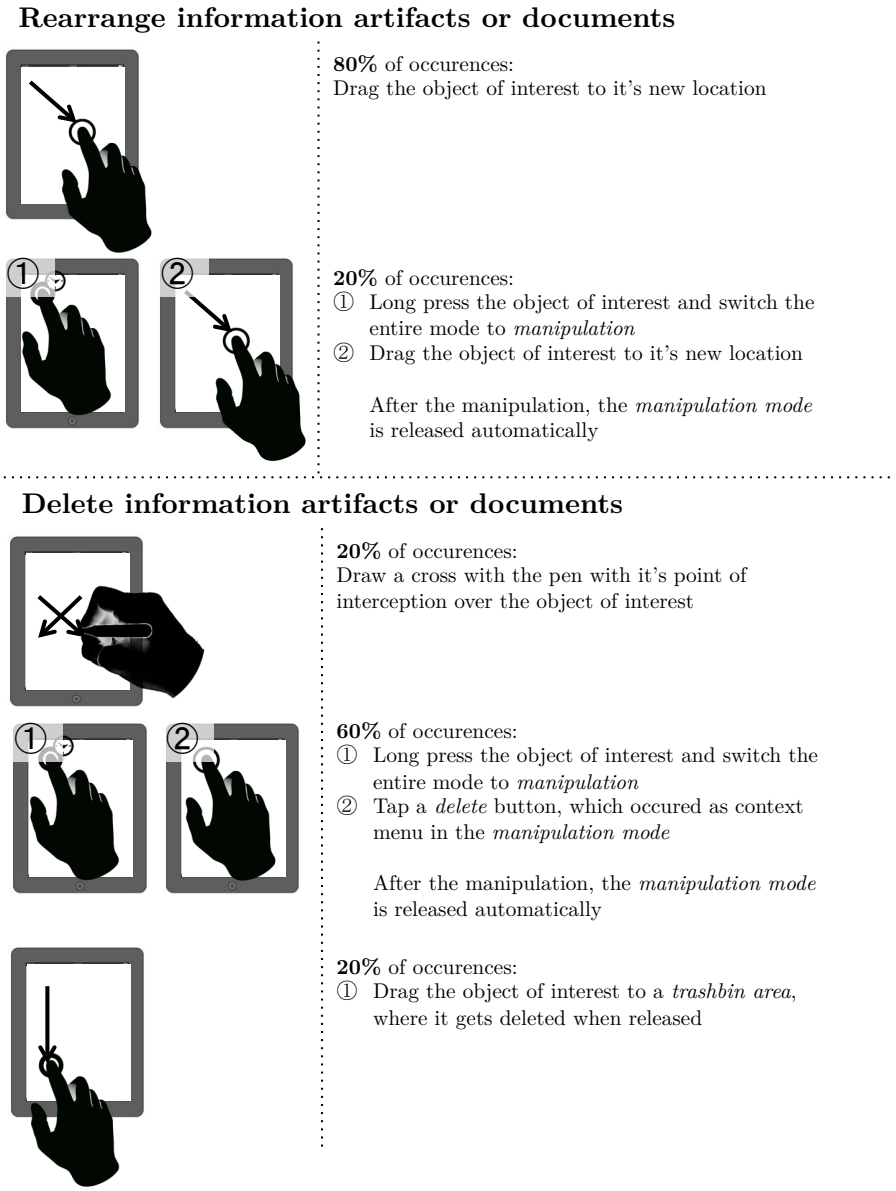


Figure 25: Preliminary Gesture Study – Operating; participant's gestures regarding the individual approach of task solving

In any case, just two subjects mentioned and used the pen for clustering purposes, as the pen enables the user to draw a circle with higher radius in comparison to the direct touch distance (see Figure 26). Other participants, which made use of touch interaction for clustering items invented

new approaches for navigating on the landscape, because single touch gestures (drawing certain shapes with the finger) are blocked by their original interaction approach. For example, they could imagine to navigate through the landscape by scrolling with two fingers.

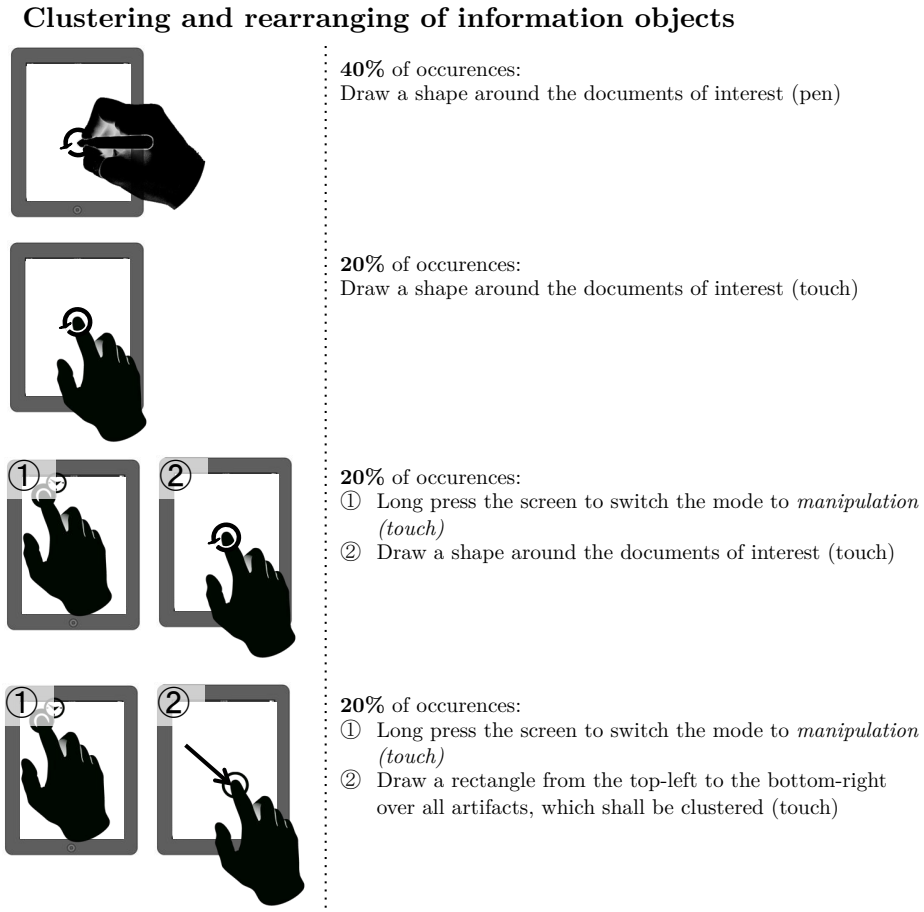


Figure 26: Preliminary Gesture Study – Operating; participant's gestures regarding the individual approach of task solving

Less than a half of the participating subjects use the pen for manipulating their information artifacts, while the resulting movements are mostly equal across both modalities.[15] In contrast, to the touch modality, which is rated as most useful, the necessity of a pen for operating purposes is rated very low (see Figure 27). As participants are satisfied with their solution meth-

[15] Text manipulation was not examined. Part of the investigation are just repositioning, clustering and deleting of information objects.

ods and results, which confirms the expressiveness of the results regarding the modalities and their utility.

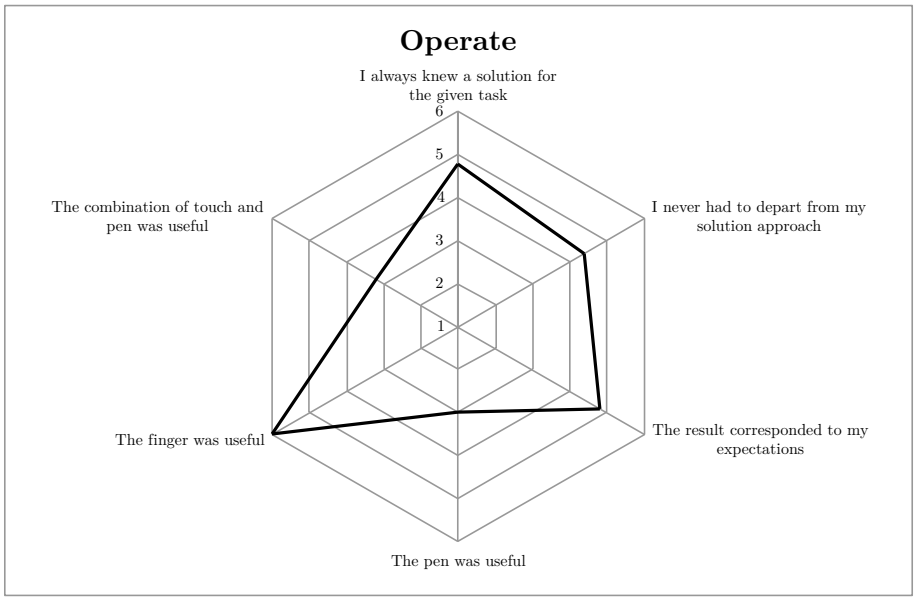


Figure 27: Preliminary Gesture Study – Operating; participant's rating regarding the individual approach of task solving

Summary

Across the four regarded working processes, touch interaction is rated as more necessary than pen interaction. Nonetheless, pen interaction is considered almost as useful as touch interaction for parsing and selection purposes. Based on interaction approaches of the physical world, subjects used the pen for annotation purposes, such as referencing and selecting information artifacts. In processes with focus on navigation and manipulation tasks, participants made use of direct manipulation through touch gestures.
Against this background, the pen interaction is considered just partly useful across the entire processes of individual scientific working. With an eye towards common physical traits, these findings verify interaction approaches of the physical world. Readers also navigate through a document by skimming with their hands. Enriching these common traits with adequate functionalities, provided by the digital background, a system for supporting *active reading* shall be established. It shall support pen and touch interaction and is focussed on interaction purposes on a tablet computer as single device solution.
Due to the hardware constraints and the focus of the whole *active reading* procedures, the browsing component on a *macro layer* is refused. Aspects as emphasizing, cross-referencing and navigating through and between documents are further regarded, as these tasks are mainly executed by participants on a tablet computer and thus potentially useful in the mobile context. Rearrangement is an essential use case for building own schemata, nonetheless the focus will lie on the interdependency of both pen and touch interaction and correlated tasks. Rearranging tasks were solved on the large wall, because users required additional space to gain an overview of the complex topic and the information set. For the mobile context it is focussed on the tablet solution at a first glance.
A further reason of the resulting interaction approach is seen in the accuracy of a pen. As the space between certain lines or of visualized text is smaller than the user's finger thickness, participants could run into trouble for working precisely with their fingers. The pen's tip offers a very small ground level on the tablet's surface, which is positionable with higher correctness [6].
Although it is necessary for a productive system to fit seamlessly in everyday work processes, just generated interaction approaches are investigated. In the following, a prototype system and it's interaction implementations will be described, which will then be investigated with respect to pure physical or pure digital interaction habits.

4.2 System Design

The gesture study illustrated that users mainly performed on the tablet computer, although they were offered larger displays for interaction purposes. Nevertheless, the system's devices are limited to tablet computers and a pen as additional input tool. With respect to the hardware setting, the visualization takes place on a single display tablet computer.
The document visualization will focus on textual visualization, which "should be as sophisticated as that of the paper book"[62]. In contrast to an established *page layout* by nowadays physical documents, the system's design makes use of a *scroll layout*[16]. The *scroll layout* offers the advantage to not separate the text in different fragmentations, so the text is visualized as a whole, through which the reader is enabled to navigate fluently. Furthermore, the continuous text layout shall not distract the user, due to breaking off text abstracts or sentences. Certainly, the *scroll layout* has to master different challenges as *footnotes* or *page references* have to be solved. Nevertheless, the coherent text visualization approach is considered as opportunity for the reader to keep up reading fluently.
The *scroll layout* requires additional mechanisms to support the reader with a required document overview and of course with the consciousness of the current progress in a document. A document overview, which displays the entire document with smaller font size is used to fasten up the retrieval of certain document milestones[17]. Furthermore, the text overview is used as indicating the current reading progress in a document through emphasizing the currently visible text frame in the document with a frame (see Figure 28).

[16] Just as scrolls of papyrus or paper, the layout is a continuous document visualization.

[17] Here, a milestone is defined as information object, which helps users to orient themselves in the document, whether through images, different font sizes, emphases or annotations.

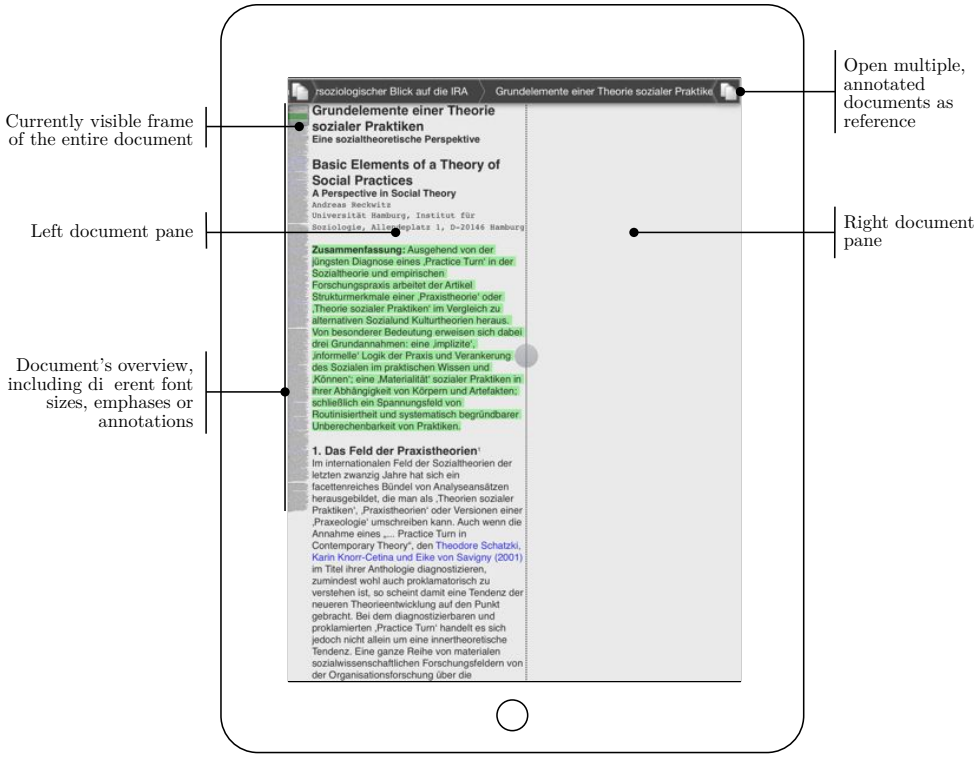


Figure 28: System design of a scroll layout and the content's overview with multiple document management support

An additional support for *active readers* shall be provided by laying multiple documents next to each other. Multiple documents also includes to make use of twice the same document, as former text passages might be relevant and the reader requires to keep both text abstracts in focus. The software solution thus makes use of a left and a right document pane where documents can be opened.

The visual appearance of the application is kept on a low level. For better evaluation purposes, the document's layout (including images or charts) is rudimentary limited to text but could be naturally extended to any kind of media type. The main focus of attention for the system design in general lies on the continuous *scroll layout* and the opportunity of multiple document management for the reader. Furthermore, most of the identified active reading approaches (see 2.1) are included in the system's design (see Table 12):

Approach	Support
Underlining	Supported in the common *document mode*
Highlighting	Supported in the common*document mode*
Formfilling of keywords	Supported in the *annotation mode*
Vertical line at an abstract's margin	Supported in both *document mode* and *annotation mode*
Note certain aspects at the margin	Annotations are left at the document's margin (*document mode*, notes are made in the *annotation mode*
Bookmark most relevant pages	Not supported, as there is no page layout. Instead emphases made by the user are visualized in the *document's overview*
Mark the author's line of argument enumerating the arguments	Supported in the *annotation mode*
Reference text passages among themselves	Supported in the *annotation mode*, also visualized in the *document mode*

Table 12: Behavioral types of active reading, supported by the system design

The system layout in general has been introduced and will now be explained in detail with respect to both input modalities: *pen* and *touch interaction.*

4.3 Pen Interaction

> "Improving accuracy and reliability can also increase efficiency. Good validation and error checking on entry mean less information needs to be reentered and fewer bad transactions need to be corrected later."
>
> *Constantine, Larry L. & Lockwood, Lucy A. D.* [10:312]

The findings of the preliminary gesture study confirm the necessity of a pen's application for scientific working. Although the tool is not transferrable throughout all processes of *active reading*, the annotation and selection process are mainly covered. In contrast to real world interaction, users did not make use of rulers or a bunch of different markers or pens, they simply stuck to one single pen. Sticking to one pen for input eases the complexity for the reader, the more tools are provided, the more the user has to distinguish between the tool-related functionalities and features.

Nevertheless, a limited amount of offered pens results in assigning all functionalities to one single tool, while not affecting each functionalities among themselves.
Brandl et al. identified an input categorization with respect to touch and pen interaction [6]. This categorization takes the dominant hand (DH) and the non-dominant hand (NDH) into account, when interacting through touch or pen with a device, as both hands have to be considered for multi manual input (see Figure 29). With respect to the examined tools (pen

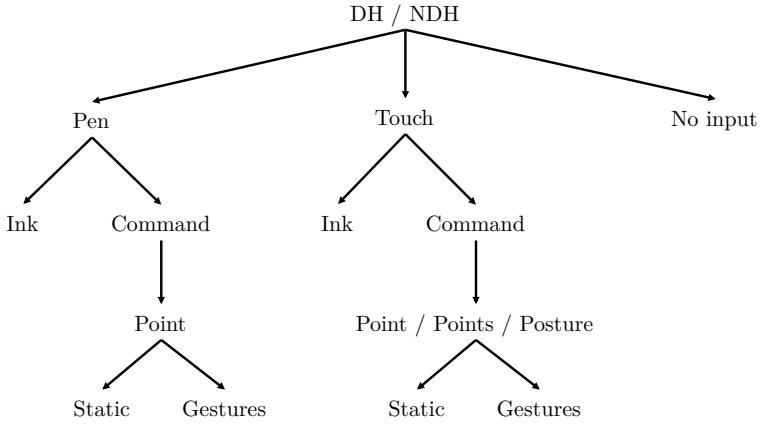


Figure 29: Input categorization for user's tools in bimanual interaction (based on [6])

and touch) users are thus able to choose between either tool or none at all. The reaction of the system, resulting from the input is further categorized into *inking* or a *command*, the system shall process. Inking describes common writing or drawing of strokes and shapes. Commands are related to the tool's properties. As a pen (usually) consists of a single tip, which is triggering the input, the pen's input is restricted to this singular point. In contrast to the single point of pens, users can make use of five fingers per hand when interacting with either hand. In addition to the multiple amount of points, Brandl et al. mention *postures*, which break down into *commands* (e.g. two fingers form a line, which could trigger a function) or more *complex gestures* (e.g. zooming where touch position over time indicates a certain zoom scale).

Regarding Brandl et al. users are thus able to interact with both hands through pen and touch and idle with either tool respectively. With respect to the preliminary user study, the pen interaction is just performed with the dominant hand, which restricts the amount of possible combinations

(see Figure 30), whereas "no input" by both hands is disregarded as well.

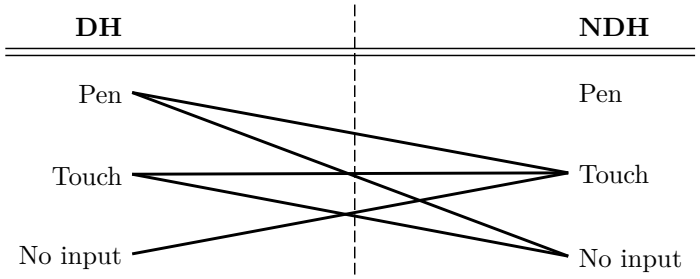


Figure 30: Considered possible combinations for the dominant - and non-dominant hand with respect to the tools

Referring to former investigations, users expected the pen mainly to ink the canvas. Drawn shapes are then used implicitly to illustrate relevant text passages (e.g. an exclamation mark). With respect to the occurrences of gestures, no commands were triggered with a single point of the pen. Commands were rather triggered through postures (e.g. a circle was used to cluster the containing objects). The input categorization is thus extended due to the *lazy interaction approaches*, where users stroke certain figures for triggering functionalities as gestures (see Figure 31).

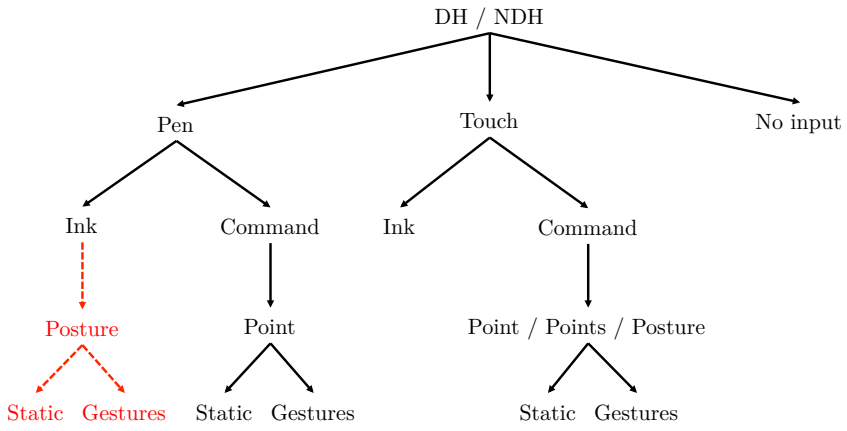


Figure 31: Considered possible combinations for the dominant - and non-dominant hand with respect to the tools

As the pointing command of the pen was not used at all, but the pen is mainly used for annotation and selection purposes, the color-mode is also triggered by the pen. This is motivated by the complexity of derived courses

of action: users opened a context menu through touch, selected the color and closed the context menu. It is assumable that users did not think of simpler solutions, as they were focussed on the paper-tablet's display and drew sample boards on the screen. The sample board for different classifications of emphases is thus transferred to the border of the tablet computer, to avoid additional menus that cover document areas. Due to the users interaction approaches, the color-selection was at first performed by touch input [62], which was refused after first testing of the software, as the rest of the selection procedures is performed by pen input. To offer a consistent interaction technique for highlighting and annotating, the color-selection is triggered through pointing commands on corresponding colors of the sample board with the pen (see Figure 32).

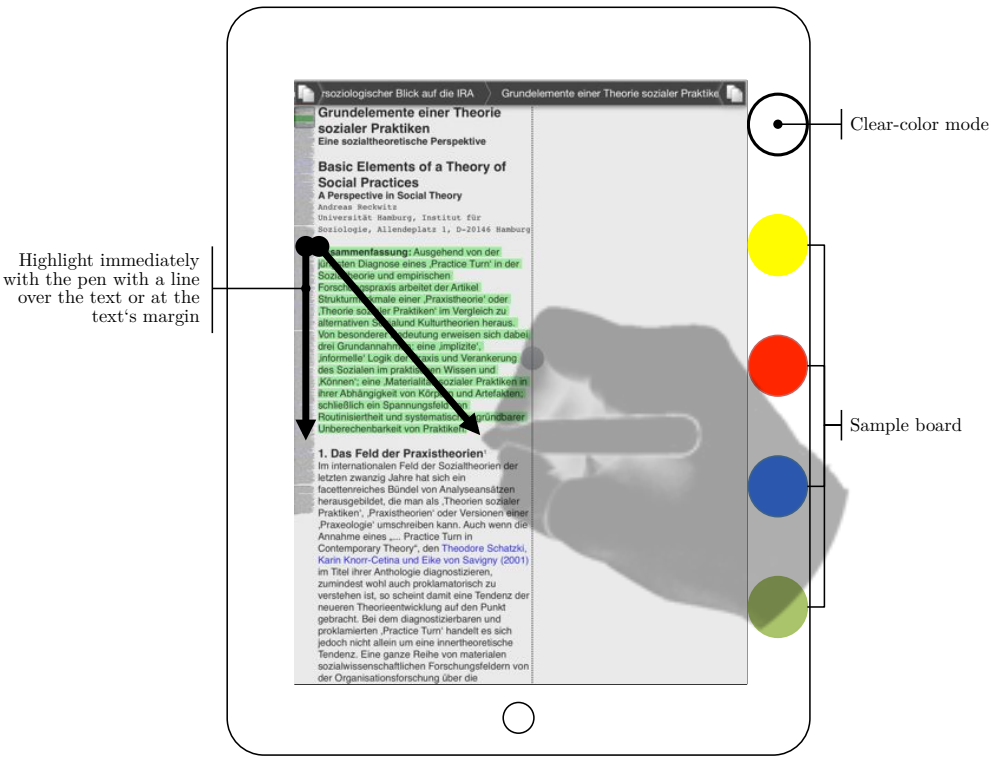


Figure 32: Pen interaction for text emphasizing and color-selection

As the selection procedure is straight forward, with respect to the defined gestures, the derived annotation mode and the correlated interaction technique is described. The physical world offers *active readers* the opportunity

to note at the margin of text or to use a notebook. Digital documents mostly make use of sticky notes, where an icon illustrates the user that an annotation was left earlier. Investigations have shown that subjects "wanted to regard annotations as a separate layer of the document [...] that were perceptually distinct from the underlying text"[42]. Taking a separate layer for annotations into consideration results in a kind of notebook that overlays the documents of interest. If offered a separate layer where annotations are made, user could also copy emphasized text passages into this specific *annotation layer* and rearrange text parts. The *direct linking*, mentioned by a subject who desired cross-referencing through drawing a line between both information artifacts, would be thinkable, as document interaction could still be supported below the *annotation layer* (see Figure 33).

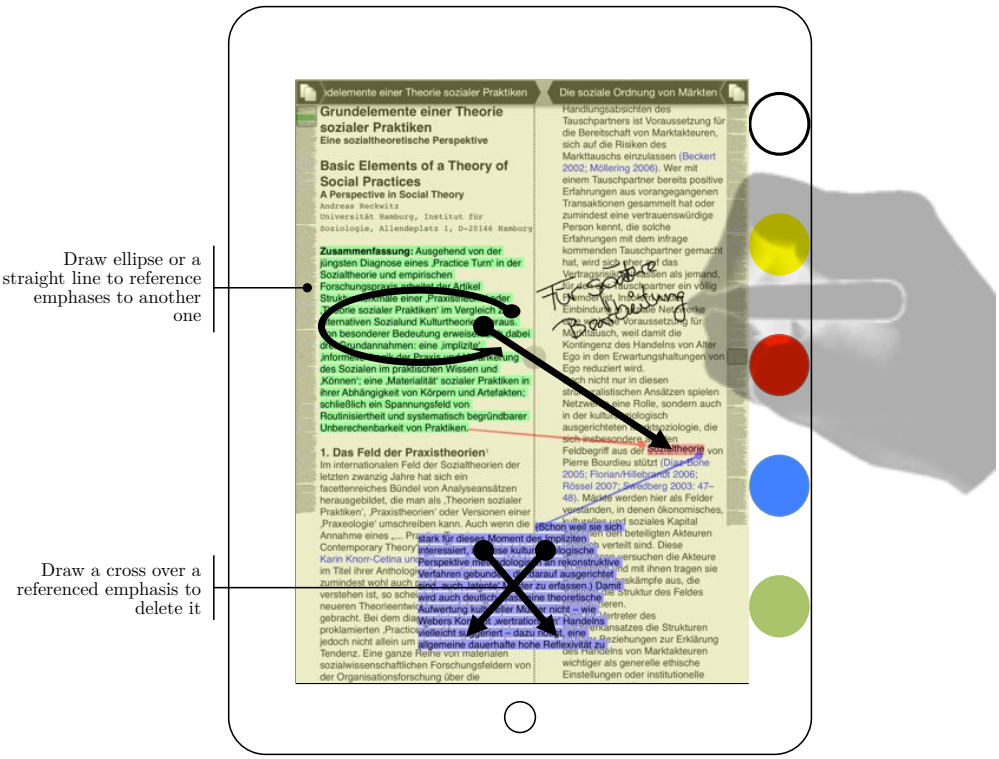


Figure 33: Pen interaction techniques to cross-reference and write in a separate annotation layer overlying opened text documents

Due to the posture gestures on the *annotation layer* and the inking ability for handwritten annotations, the common emphasizing ability with drawing a line over a document's text is disabled, as the commands would otherwise conflict each other. Thus the users are mainly able to reference emphases

with each other and make own notes.

4.4 Touch Interaction

Touch input has become a widespread and common interaction technique for interactive surfaces, such as tablet computers, smartphones or tabletop computers. It's advantages of direct input and multitouch gestures without using an additional device are well-known. The investigated gesture study proves once again that it is the most preferred way to interact with digital documents for *active reading* purposes, although some aspects were solved with other tools.
Nevertheless, certain issues might hinder a fluent *active reading* interaction. For example, barriers occur due to the fact of the text's size and the resulting size of objects with which the reader requires to interact.

With respect to browsing activities, the *macro layer* is not regarded. Thus a subset of preselected documents is assumed, which are of interest for the reader. To identify a document with respect to it's color coded topic as fast as possible, a circle is used to visualize the percentile distribution among emphases (see Figure 34). For supporting navigation across documents, referenced literature is directly linked within the document. There shall be no need for skimming through an entire document for retrieving the result of a document, which is used to look for in a library or the individual data collection. References shall be opened implicitly, when the reader taps the document in the text.
A similar approach is taken for footnotes. Footnotes or endnotes may be an essential aspect for text comprehension, as certain issues are further explained. Regarding footnotes, different challenges are mentionable. Long text of footnotes shall not reformat the entire document. It is thus used to break footnotes into two parts, if they were too large for one page, and are continued on the upcoming pages. This might distract readers, as they do not just have to leave their current reading spot on the current page but also have to leave the current page to continue reading the footnote. This aspect is even extended by endnotes, for which a reader has to behave as with references. Readers shall no longer look to the bottom of a page but shall rather simply open the footnote at it's context and not lose their reading progress, when they finished reading the footnote.
To keep the progress within the current document, a preview bar is offered on the side next to the border where annotations and emphases are also visualized. The reader shall be easier able to retrieve certain text passages

of interest, if former emphases or text passages have to be looked up. In addition, the most recent reading progress is restored, when a former document is opened again to support the user's self-management. This restoring progress is presumed to dog-ears in printed documents, where the researcher is able to open the most recent page of a certain document as well. Thus, the user is provided to continue reading, where the document was left the last time, because of a reference or because something had to be looked up in a different document.

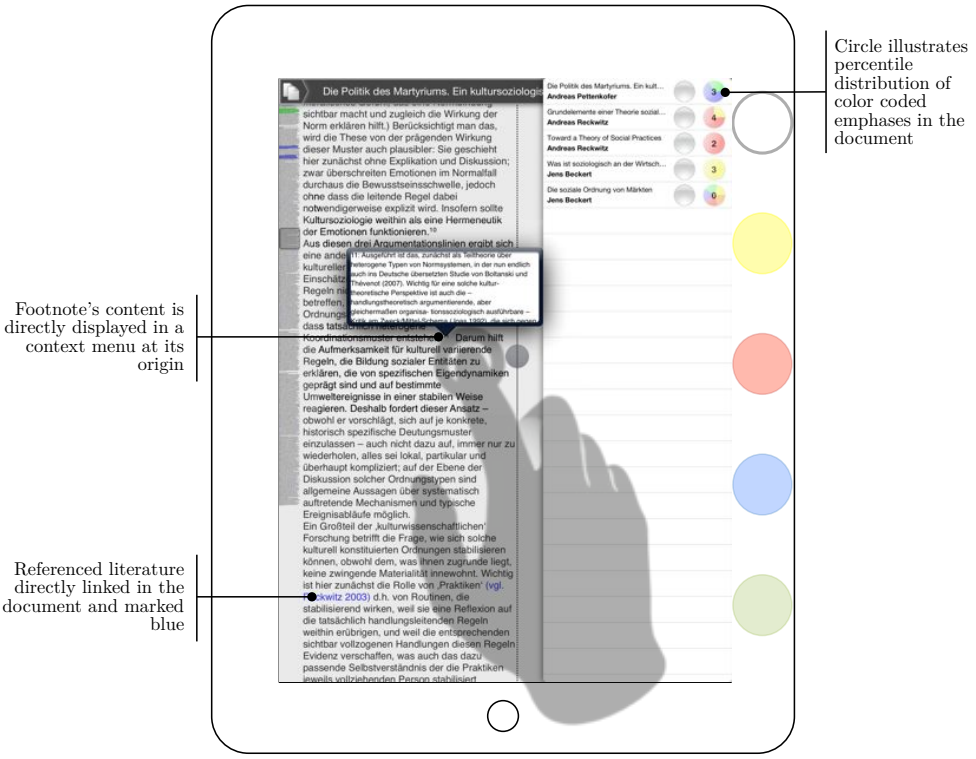


Figure 34: Touch interaction in a document for supporting browsing and parsing tasks

The reader is able to fasten up navigation across documents through directly linked literature in the text. Nevertheless, this meta-navigation across documents shall not distract or confuse the user, when retrieving the object of origin. Furthermore, it is considered to open two documents in parallel. This could be useful, if one document was opened on both areas, as a reader requires a certain abstract at the beginning of the document but wants to continue processing with reading. On the other side, related documents for the current document of interest could be opened, without losing the

current text abstract of the main document to work with.
The overview shall be rudimentary supported through breadcrumb navigation. As a basis, the user is able to open a document on the left and right pane of the application, from which *diffused reading* is initiated (see Figure 35). Because there is just one single bar, which covers the left and right document pane (two navigation paths), the user is able to scroll through the visualized items, if the amount exceeds the bar's width.

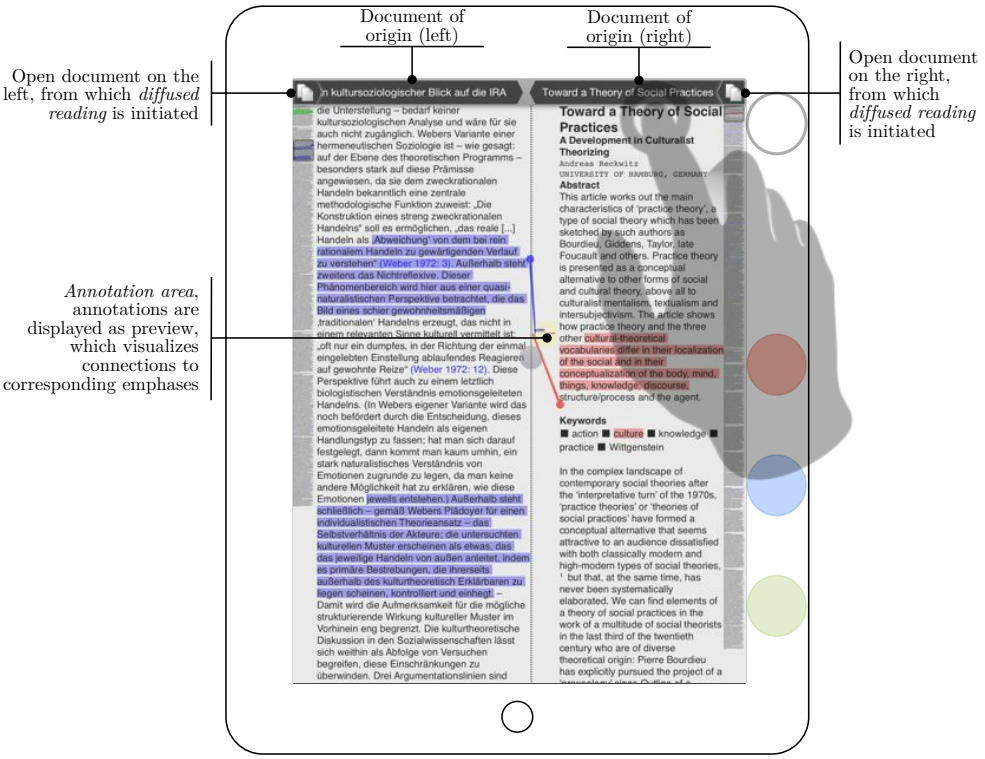


Figure 35: Touch interaction in a document for supporting meta-navigation tasks and multiple document management

Additionally to cross-document navigation and an overview of annotations, readers optimal font size of text for best reading performance differs [12]. Text processing of *active readers* thus requires an option for scaling the text. A further benefit of text scalability is expressed in better touch interaction possibilities, as the text size might be adapted to the fingers size. The scaling opportunity could be established on two ways: either by simply zooming into the text document (as it is well-known with a pinching gesture) or with a slider, which represents the text's font size. The zooming functionality was avoided to avoid two-dimensional scrolling for the user,

when navigating through the document. Furthermore, a remapping of the pinching gesture to scaling the text's size might irritate users. As the system already offers a control for changing the document's width where it's content is also reformatted on the *x-axis*, this specific control could be used on the *y-axis* (see Figure 36). To keep the reader's current context in the document, the centered text point is used as reference[18] when scaling or formatting and always displayed in the middle of the view.

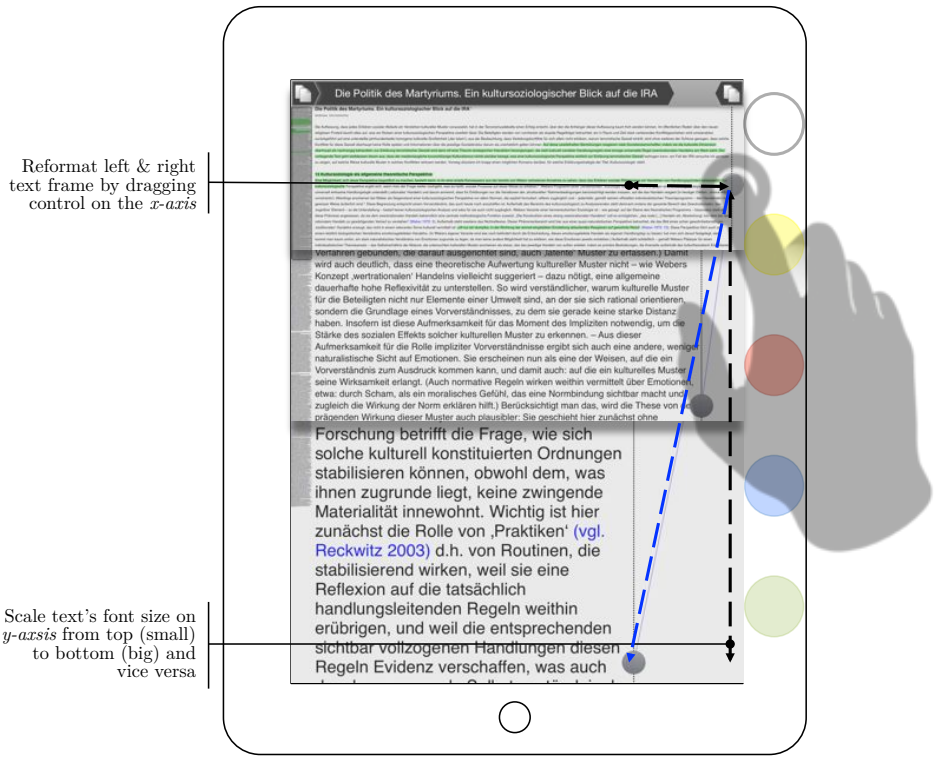


Figure 36: Format and scale control for fast overview and easy laying out with a pan gesture

By now, text comprehension purposes such as laying out multiple documents' management and an annotation overview is described. A further

[18] The center of the current text frame is used as current progress in the document schematically. Although the user's focus point may vary on the entire document view, technical constraints limit the detection of the reader's current focus point, as this is not the main focus of the *active reading* support. In future, this option could be covered by an eye-tracker or other proprietary products, such as *Google Glass* - http://www.google.com/glass/start/

requirement for supporting the reader in *active reading* is a search functionality. The search functionality is initiated through query by example (see chapter 3.2) and thus based on text interaction, while the search is conducted in the entire document's library of the user. As initially described, text's font size might be too small for an accurate and appropriate text interaction. While the functionality of text scaling with keeping the current focus point is offered, the detour of scaling text up, trigger the word through selecting a word and scaling the text down is, nevertheless, not appropriate. As straight interaction, without the necessity of additional interaction steps, a direct text interaction shall be offered even when the text's font size is way smaller than a fingers' thickness. An appropriate approach was demonstrated by Vogel & Baudisch, who proofed the accuracy of different kinds of magnifiers [60]. The approach of a magnifier is enriched by a common cross hairs visualization to illustrate the user, which specific point is currently in focus of the magnifier and would trigger a text search, when the finger is released (see Figure 37).

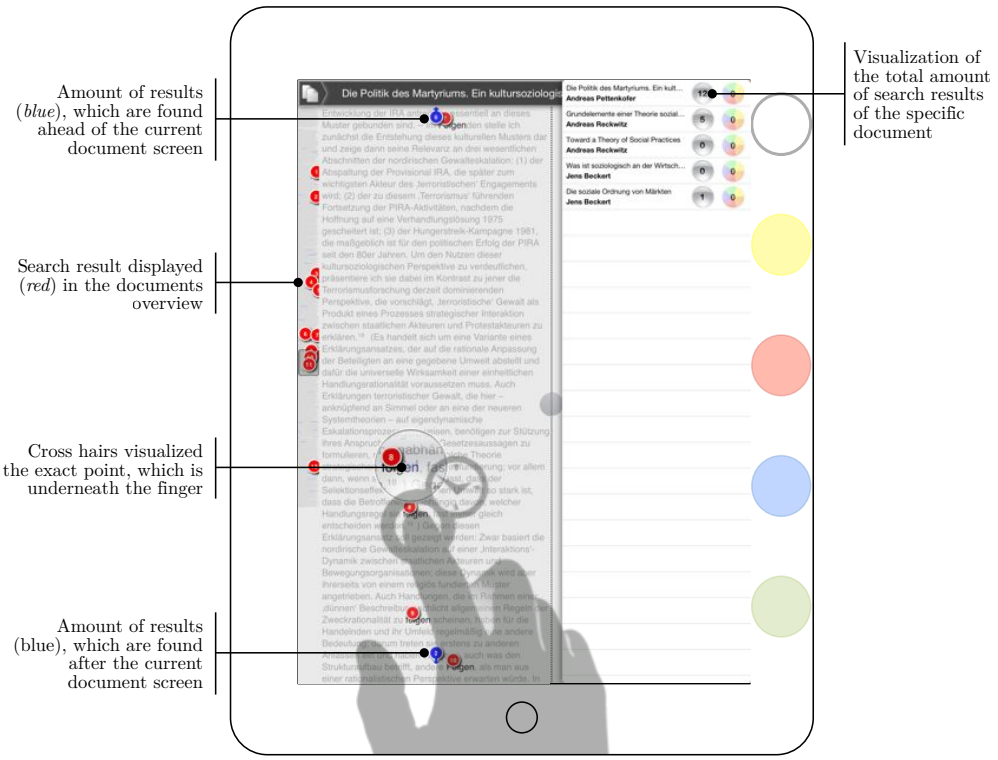


Figure 37: Visualizing the text search's results and the interaction approach

The results in the current document are then emphasized, by fading the rest of the text out and by displaying the result's index number next to the result in the overview and the document's frame. Search results in documents of the user's library are illustrated by the total amount of occurrences in the specific document. In case, a user opens one of the documents with a search result, the system will automatically navigate to it's first occurrence in the document.

With respect to possible combinations for bimodal input, the combinations are narrowed down to not overstrain the reader with a complex amount of interaction techniques, as the reader's focus shall lie on understanding and analyzing certain texts. Thus the touch interaction approach is limited to single touch only, as an interaction with two hands simultaneously only occurred for pen and touch interaction in parallel.
Touch interaction is performed (also with respect to the conducted preliminary gesture study) with either hand, users scroll with both hands and select certain elements on the tablet computer's screen with respect to object's positions on the current surface. The user input is mainly limited on a *single point* (e.g. when a certain word is tapped or a document is opened). Furthermore, long press gestures are offered to enrich the common reading procedure with additional functionalities, such as text search or rearranging and manipulation of emphases in the annotation mode. The long press gestures are considered as rudimentary *postures*, because a certain period of time is required to trigger the events. After triggering these events, the single point of the current touch is again regarded, which makes *multiple points* as input command obsolete. A final constraint for making the software solution as simple as possible for possible input combinations, is the restriction of *inking* or painting with the finger. The gesture study has proven that users prefer the pen as they are used to it from the physical world and because of the pen's accuracy capabilities.
With respect to the initially described input categorization by Brandl et al. the following diagram of input possibilities is derived:

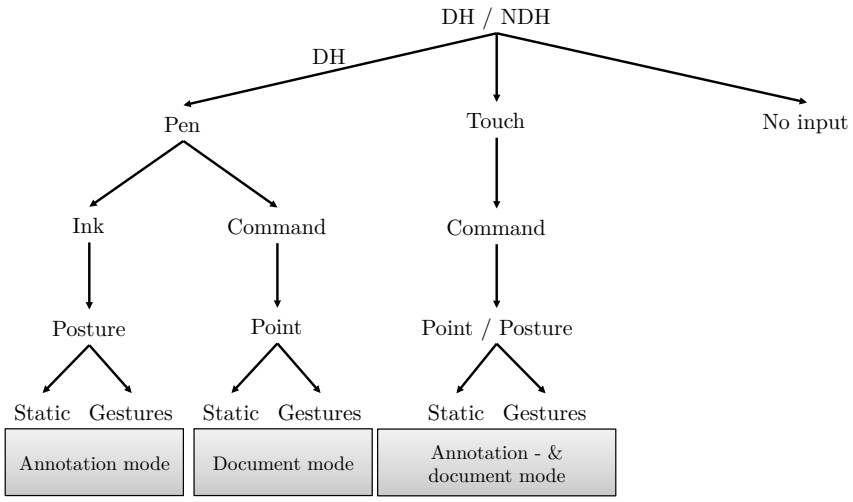


Figure 38: Modified, final input categorization for users with respect to bimanual and bimodal input

Still, the developed interaction approach is just a proposal, which might support *active readers* in working with digital text documents in the mobile context. The approach has been described in detail and is reduced to a lean interaction structure, where input modalities are combined as consistent as possible. In the following, this approach is evaluated to further classify the suitability of the combination of the pen and touch modality and it's corresponding hybrid input techniques.

5 Study: Hybrid Interaction Technique

The hybrid interaction approach has been introduced in detail. The goal of this elaboration is, nonetheless, to name adequate and appropriate ways for supporting *active reading* in the mobile context with digital or digitized documents. Particularly, one of the interests is thus to evaluate the suitability with respect to known media types. As initially described, users tend to either digitize analogous text parts or print out digital documents. They simply transfer the object of interest to the physical or digital world, with well-known traits.
Users currently have different preferences regarding either world. The approach is thus the hybrid interaction technique, which allows users to perform in a blending of both worlds. Certain manipulations are more equal to the physical world, while other aspects are closer to the digital world. To now compare this hybrid technique, a common *active reader's* scenario with a defined work flow and tasks is used to compare the hybrid interaction technique with conventional, physical documents and a proprietary, digital approach on a tablet computer.

5.1 Study Design

This chapter is addressed to other researchers in order to make research methods and the empirical approach comprehensible. At first, the interest of research is explained regarding the developed hybrid interaction technique. Then, certain conditions of the evaluation are explained for later reliability of the gained data-set or for broadening the research interests. Finally, the study setup and the operational procedure including the user's tasks are explained.

After a descriptive user study was accomplished to acquire knowledge worker's requirements when working with information objects and a preliminary ex-

perimental study with a paper-like prototype to gain insight in researcher's interaction behavior, an experimental study is held to clarify the following three research questions to indicate the most appropriate *design solution*, which will then be used to define *design guidelines*:

1. Does *hybrid interactive reading in the mobile context* enable knowledge workers a subjective qualitative and/or quantitative better working experience in comparison to *conventional active reading with paper in the mobile context* with respect to satisfaction, simplicity and time efficiency?

2. Does *hybrid interactive reading in the mobile context* enable knowledge workers a subjective qualitative and/or quantitative better working experience in comparison to *pure digital active reading on tablet computers in the mobile context* with respect to satisfaction, simplicity and time efficiency?

3. Are the requires functions offered, which the users require for *active reading in the mobile context* or do they lack basic functions?

Active reading was not only investigated by its affordances and operational procedures, but also on tabletop computers. Matulic & Norrie dedicate themselves to the problem of merging "people's individual interaction practices and behavioural habits for paper and computers successfully [...] using the pen and touch"[37:616] on tabletop computers. Here, they aimed to support three main functions in their application [37]:

- Annotating
- Navigation
- Layout

In the following these three main aspects are explained and further discussed to referring argued interaction approaches. Based on the outcome of the combination of both focus points, a study design and operational procedures is derived on the basis of the formerly accomplished user study by Matulic & Norrie in 2012. Here, the interaction approaches are not compared, the focus lies on the evaluation makeup to derive a setup for an experimental user study of the hybrid interaction approach on a tablet computer.

Annotating The annotation functionality is investigated regarding the creation, a deletion process and the recalling of notes. Yet, there is no distinction between annotations, their reference points or it's notes. In the preliminary gesture study (see chapter 4.1) it is shown that users make use of different approaches for emphasizing text parts, thus the annotating is considered with respect to a "text of interest"'s granularity (word, sentence and abstract).
The deletion approach is then regarded vice versa with a white color, which deselects the corresponding text parts.
Recalling is a term, which covers qualitative aspects, such as the quality of remembering of a selected text's content. Here, the focus will rather lie on quantitative aspects. Certain aspects are taken into consideration, for example how much time is required to retrieve an annotation of interest and in which document was the annotation left. Furthermore, the identified need for navigate to referenced and correlated information artifacts shall not be distorted by a back-linking functionality. A users capacity of remembering is investigated with respect to the document's appearance and the documents overview.
To cover the entirely possibilities of referencing in documents, not just text parts and annotations shall be considered, but also referencing text passages with each other across documents, as knowledge worker's have to integrate gained insights from different documents to create new mental structures.
The function of *annotating* is thus not correlated to the investigations by Matulic & Norrie, nevertheless, it is part of their study's structure and considered in the upcoming study.

Navigation It is differentiated between sequential and random navigation in a document. Sequential navigation is a common reading behavior, readers process in the document word by word or side by side. Random movement describes a volatile navigation behavior through a document, for example, motivated by a certain text passage of interest or search results. While sequential navigation is quite static, a random approach could also be triggered by *diffused reading*, when a reader wants to navigate to another document or requires to search a word in one or multiple documents. Thus, text search is listed in the navigation procedure.
Because text search in paper-documents might distort sequential navigation in and between documents, the text search is considered as a separate aspect of interest.

Layout For fast categorization of a document's content, an opportunity is given by Matulic & Norrie to visualize a document's overview. The user is able to see all document's pages at a glance. As formerly described, an overview functionality is not regarded in detail. An overview is displayed at the left or right side, including annotations and emphases, further document visualization approaches are not focus of the evaluation.[19] Furthermore a page overview is thus not granted, as a *scroll visualization* is adopted.

Three main systems shall be compared with each other. The exploratory summative usability study is accomplished as within-subject design. The comparison approach is motivated by the opportunity given to users to better understand and compare the *hybrid approach* to *conventional paper* and a *pure digital* solution regarding either functionality and limitations. Each user shall be able to classify functionalities with respect to well-known techniques to identify weaknesses or strengths of either solution. For better comparison, each user will thus be given enough time to familiarize oneself with all systems. To measure subjective aspects as simplicity and user satisfaction, qualitative data will be acquired. Time efficiency is measured by collecting quantitative data for comparing the user's execution times of given tasks.
The sequence, in which participants interact with each system is counterbalanced to avoid learning effects and signs of fatigue. The amount of users thus has to assure that the amount of possible combinations is covered and each possible combination is covered the same times.

The target group of knowledge workers or researchers is narrowed down to students for reasons of simplicity. It is not differentiated between the course of study, because each course of study is making use of *active reading*, it is thus desired to cover different courses of study. A further dependent variable is the right-handedness of participants. The gesture study was accomplished among right-handed users and so the evaluation will be. Furthermore, the participants shall be familiar with either interaction technique. While paper based interaction is well-known, touch approbated subjectives are regarded. The interaction techniques require to be compared on an equal level, users shall not require to learn touch interaction at first, before they make use of a hybrid or pure digital system for *active reading*, which is making use of touch interaction.

[19] Fast document identification and content classification is a very complex issue on it's own, which is focussed by researchers in detail who do not mainly focus on interaction approaches [56].

The experimental study is executed in a controlled setting, which aims to simulate the mobile context. Subjectives are asked to execute given tasks when being seated and to keep all required documents in their hands or lay them on their lap. For better accessibility of pen's or highlighters, users are allowed to lay these tools on their right or left side on a table. A right and left side is offered, because the preferences of laying the pens down might differ between users. To track the user's performance, two cameras are used for recording the interaction behavior.
A prestudy has revealed that users did not sat up straight, they rather preferred to lean to the left or right. Attaching two cameras to the setting ensures the reliability of the data, as at least one camera records the user's behavior (see Figure 39).

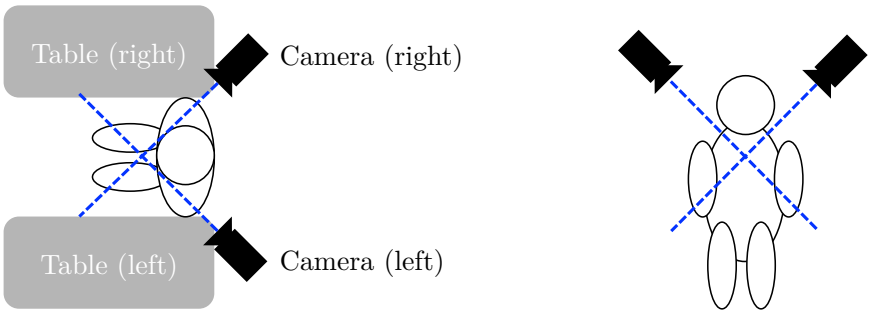


Figure 39: Study setup of a controlled setting for the mobile context. Left: view from above; Right: view from the front

Three main aspects are illustrated that are taken into consideration. In the following an analysis approach is described, how the research questions are answered and the study is conducted in detail, including hypotheses, derived independent variables and user tasks.

5.2 Analysis Methodology

To compare conventional paper based *active reading* with pure digital and the hybrid system, three main aspects (annotating, navigation and text search) are regarded. With respect to the user study by Matulic & Norrie the evaluation of interaction techniques is thus grouped in the following three sections:

1. Platform efficiency & task suitability
2. Function rating
3. System limitations and discussion

The effect size is not further regarded, as already small significances are considered as relevant for either criteria, whether it is a small effect or not. The specific trend is extrapolated and an assumption is made, which either proves or disproves a null hypothesis.

Platform Efficiency & Task Suitability

Derived from the research question, the hypotheses are defined to operationalize the measurements. The hypotheses are set into an order, in which participants will later on be asked to solve corresponding tasks, furthermore these tasks are assigned to the three focussed aspects. For a better overview of the hypotheses among the different systems, the following notation is introduced:

Approach ***P***: conventional *active reading in the mobile context* with paper
Approach ***D***: pure digital *active reading in the mobile context*
Approach ***H***: hybrid paper like *active reading in the mobile context*

Derived from the three main aspects (*annotating, navigation* and *text search*), null-hypotheses are described, which are either refused or approved. The null hypotheses H_0 are generated in comparison between either of the interaction approaches $\boldsymbol{\xi}$ (P, D or H). It is assumed that the investigated utility value (satisfaction, simplicity or time efficiency) of one input approach ξ_1 equals the investigated utility of the other input approach ξ_2, while there are always just two approaches compared with each other.

Annotating

1. $\boldsymbol{\xi_1}$ requires as much *time* **marking text passages** as $\boldsymbol{\xi_2}$
2. $\boldsymbol{\xi_1}$ requires as much *time* **annotating text passages** as $\boldsymbol{\xi_2}$
3. $\boldsymbol{\xi_1}$ requires as much *time* **referencing text passages** as $\boldsymbol{\xi_2}$
4. $\boldsymbol{\xi_1}$ is equal in *user satisfaction* rating as $\boldsymbol{\xi_2}$ regarding **annotating**

Navigation

5. $\boldsymbol{\xi_1}$ requires as much *time* **retrieving documents** as $\boldsymbol{\xi_2}$
6. $\boldsymbol{\xi_1}$ requires as much *time* **locating chapters** as $\boldsymbol{\xi_2}$
7. $\boldsymbol{\xi_1}$ is equal in *user satisfaction* rating as $\boldsymbol{\xi_2}$ regarding **(cross-document) navigation**

Text search

8. $\boldsymbol{\xi_1}$ requires as much *time* **locating words** as $\boldsymbol{\xi_2}$
9. $\boldsymbol{\xi_1}$ requires as much *time* **retrieving emphasized passages** as $\boldsymbol{\xi_2}$
10. $\boldsymbol{\xi_1}$ requires to scan as much *documents* **retrieving emphasized passages** as $\boldsymbol{\xi_2}$
11. $\boldsymbol{\xi_1}$ is equal in *user satisfaction* rating as $\boldsymbol{\xi_2}$ regarding **(cross-document) text search**

The general null-hypotheses[20] are subdivided into three related atomic null hypotheses to provide a pairwise comparison. The derived atomic null hypotheses from each hypothesis pairing, result in the following pairs:

- H & P
- H & D
- D & P

The corresponding null hypotheses of the hybrid - H and paper based approach P are noted as H_0^{HP}, accordingly the null hypotheses for the hybrid and digital approach H_0^{HD} and the comparison of pure digital interaction and paper based working H_0^{DP}.

Exemplary the fifth pairing is subdivided into:
$\mathrm{H}_{0,5}^{HP}$: $\boldsymbol{H}$ requires as much *time* **retrieving documents** as $\boldsymbol{P}$
$\mathrm{H}_{0,5}^{HD}$: $\boldsymbol{H}$ requires as much *time* **retrieving documents** as $\boldsymbol{D}$
$\mathrm{H}_{0,5}^{DP}$: $\boldsymbol{D}$ requires as much *time* **retrieving documents** as $\boldsymbol{P}$

[20] The hypotheses are once again summarized in Appendix 6.16, which can opened to keep an overview of all hypotheses and their classification.

And the corresponding alternative hypotheses H_1:
$H_{1,5}^{HP}$: ***H*** requires more or less *time* **retrieving documents** than ***P***
$H_{1,5}^{HD}$: ***H*** requires more or less *time* **retrieving documents** than ***D***
$H_{1,5}^{DP}$: ***D*** requires more or less *time* **retrieving documents** than ***P***

The user satisfaction and simplicity are subjectively examined. Users are asked to participate in a NASA Task Load Index (TLX)[21] for each considered aspect and each interaction approach, used to assess the subjective workload of each user. At the end, nine NASA TLX forms are filled out by the user (see Table 13):

Interaction Approach	Aspect of NASA TLX form
Paper based	° Navigation ° Text search ° Annotation
Pure digital	° Navigation ° Text search ° Annotation
Hybrid	° Navigation ° Text search ° Annotation

Table 13: Evaluating each interaction approach with each considered aspect

The TLX is used to compute the overall score of the workload, because "[e]xperienced workload and physiological consequences reflect the effect on an operator of performing a task"[21]. This specific effect is regarded as cause of decreased task suitability.

Function Rating

Participants are introduced in the systems to ensure comparability. Finally, they shall rate the hybrid interaction approach with respect to the other systems' functionalities, whether they enjoyed this approach or faced problems. A direct comparison of each feature is not investigated, as the preliminary gesture study already revealed that users have a high amount of different solution approaches and they shall not be forced to select one of them, as each approach is appropriate for a certain circumstance.

[21] http://humansystems.arc.nasa.gov/groups/TLX/, seen 10.01.2013

With respect to the user's requirements, the following system functionalities, which were developed, are regarded:

- Formatting
- Emphasizing
- Cross-document navigation
- Multiple document management
- Text search functionality
- Annotating: referencing
- Annotating: writing
- Annotating: deleting

Participants are asked to fill out this form at the end of all tasks. According to the NASA TLX, each functionality aspect ranges on a scale from 0 to 100, where the user votes from the low utility (0) regarding each functionality to it's high utility (100).
This survey aims to identify opportunities to extend a hybrid interaction system or to validate the research questions with an adequate support of users' requirements regarding *active reading*.

System Limitations and Discussion

Mainly, the system's functionalities shall be rated, nevertheless, a certain insight is expected by analyzing the systems constraints and limitations. For example, the tablet's physical attributes (weight, size, etc.) might distract certain user's when *reading* different texts *active*. Furthermore, the input modality differs from common tablet computers and requires adjustment of the user to work in an appropriate way. Due to the physical attributes, the multi modal - and bimanual input, the following limitations are regarded also in dependance of Matulic & Norrie [37]:

- Display size (too small)
- Palm rejection problem
- Text visualization (too small or not sharp enough)
- Delayed pen strokes

- General slowness
- Difficulty with Multitouch operations
- Difficulty with Pen + Touch operations
- Misrecognized pen postures

Just as the *functionality rating*, users are asked to classify the drawback of either identified limitation or constraint from few problematic (0) to very problematic (100). The findings based on this data could be used to further develop the hybrid system or to identify weaknesses of the hybrid interaction approach in comparison to the other two solutions. In addition, users are instructed to *think aloud* to better identify a user's problem or line of thought with respect to either solution.

Tasks and Additional Data

Navigation, *text search* and *annotation* are considered as main aspects to evaluate. Based on the identified work processes of the users and the main focus on the work processes of *browsing* and *parsing*, the following tasks derive. Each solution approach covers all three kinds of types to support counterbalancing across the tasks and systems, illustrated by the following tasks (*Typ 1*):

1. Please open the document: **"Andreas Pettenkofer: Die Politik des Martyriums"**.
2. Please navigate through the document to the beginning of **chapter 14**.
3. You come across an interesting word in the text passage **"stabil"**. Please emphasize the word, so you will later on be easier able to recognize it.
4. You are interested in the word **"stabil"** and look for other abstracts in the current document where the word occurs. The sentence in the **middle of chapter 13** in which the word occurs twice in a sentence seems to be highly relevant. Navigate to the sentence: **"Wichtig ist hier zunächst die Rolle [...] jeweils vollziehenden Person stabilisiert."**.
5. Please emphasize the sentence **"Wichtig ist hier zunächst die Rolle [...] jeweils vollziehenden Person stabilisiert."**, so you will later on be easier able to recognize it.

6. The sentence references to another document. Please localize and open the referenced document written by **Reckwitz 2003** (if necessary, please take a look in the references).

7. The first abstract of the document seems to be relevant as well. Please emphasize the abstract, too: **"Zusammenfassung: Ausgehend von der jüngsten [...] begründbarer Unberechenbarkeit von Praktiken."**.

8. In the abstract "Zusammenfassung", the 11th word **"Sozialtheorie"** is new to you. Please look for this word **"Sozialtheorie"** in your documents collection. You may remember yourself that the word occurs in the document **"Die soziale Ordnung von Märkten"** in the last part of **chapter 2.2** (1st result).

9. You found an interesting sentence in the document **"Die soziale Ordnung von Märkten"**. Please emphasize the word **"Sozialtheorie"** with another color and note the emphasis with the words: **"Für spätere Bearbeitung"**.

10. Due to substantive relationship you want to reference the annotated word with the former abstract. Please reference the abstract **"Zusammenfassung: Ausgehend von der jüngsten [...] begründbarer Unberechenbarkeit von Praktiken."** with the annotated word **"Sozialtheorie"**.

11. You do not need the emphasized sentence **"Wichtig ist hier zunächst die Rolle [...] jeweils vollziehenden Person stabilisiert."** anymore. Please remove the emphasis of the selected sentence.

12. You do not need the emphasized abstract **"Zusammenfassung: Ausgehend von der jüngsten [...] begründbarer Unberechenbarkeit von Praktiken."** anymore. Please open the document with the abstract and remove the emphasis of the selected abstract. If necessary, please do also delete your annotations.

13. You do not need the emphasized word **"Sozialtheorie"** anymore. Please open the document with the word and remove the emphasis of the selected word. If necessary, please do also delete your annotations.

For later evaluation purposes, these tasks are once again assigned to the regarded tasks and their related main aspects. The evaluation is thus focussing on high detailed atomic user tasks but also on the aspects and the

work process as a whole with low task granularity. For further hypotheses testing, the tasks are assigned to the different (time-considered) hypotheses (see Table 14), to later on evaluate the different main aspects.

Hypothesis	Tasks
1	3,5,7
2	9
3	10
5	1,6
6	2
8	4,8
9	11,12,13

Table 14: User tasks assigned to considered hypotheses

The tasks have to be solved with an underlying set of five documents, each comprising 40.000 characters. The documents are scientific publications of the social sciences to enhance the feeling of scientific working for the participants. The bibliography entries were limited to the ones occurring within these 40.000 characters, although the original documents were exceeding this length, to avoid side effects due to missing references in the document. Before starting with each solution approach, users are introduced into either system and have three additional learning documents to get into touch with the interaction approaches. The learning phase covers all required interaction techniques to guarantee that a user has not to think about how to interact to achieve a certain system state.

Conventional paper The documents for the paper-based approach are stapled, so the user is easier able to switch between and across documents. Additionally, the bibliography with all references is attached to the end of the document. Common text markers and a pen are given to the user to distinguish between emphasizing and writing, just to offer a common working environment.

Digital The pure digital solution is based on *iBooks*. *iBooks* was introduced in January 2012 as substitute for school books due to certain digital benefits.[22] It offers the identified *active reading* functionalities and is used

[22] http://www.popsci.com/gadgets/article/2012-01/apples-new-ibooks-app-ipad-aims-replace-high-school-textbooks, seen February 2012

for learning and knowledge generation processes.
The documents for *iBooks* were generated by using *iBooks Author*[23], which allowed to format the text and set up the chapters for faster user navigation. Each document (including the learning documents) was exported and transferred to the device. To separate the learning documents from the documents of the user study, two distinct folders were created, which contained the related data.

Hybrid The text data of the documents was transferred in the developed prototype. Furthermore, text parts with specific formatting, such as headlines or document references were indexed for the document renderer to provide a similar document representation. Additionally, the text's footnotes and references were included, to support cross-document navigation for the user.
Based on the hybrid interaction approach, both touch and pen have to work as accurate as possible. Users were thus asked to calibrate the pen in the learning phase, while they familiarize themselves with the system and the pen's accuracy.

As measure of precaution for application crashes, battery issues or anything else, which might occur when users interact with either system, the following escalation chain was investigated:

1. Take the documents / system from the user, because the time is stopped. The user shall not be able to profit from the error and gain insight in the documents.

2. Talk to the user what has happened or what might have been expected. React to the expectations if applicable.

3. Fix the problem and recover the state of the user, which was present when the issue occurred.

4. Make sure that the user is ready to continue.

5. Hand the documents / system back to the user and start the time.

In addition to the data, collected by time recording and the form sheets, further data collection approaches are considered: video and log data of the tablet computer. The video analysis is used to note user's thoughts and comments when they interact with either system, furthermore it is used to

[23] http://www.apple.com/ibooks-author/, seen February 2012

manually measure the required time.
A further approach for tracking the user's interaction technique is the utilization of a log file. Although it is not possible to include a log file into the proprietary digital software solution or on common physical paper, the interaction and courses of action with the hybrid prototype is tracked. The data is streamed into a text file and could reveal additional insights in interaction problems or drawn strokes with the pen. To differentiate between touch interaction and pen interaction, two perl scripts are implemented, which cut the data of interest out of the text file (see Appendix 6.6 and 6.7), so the data is able to be post processed with additional software tools in the evaluation process.

5.3 Evaluation

Seven participants (all right-handed) took part in the experimental study. One participant was, nonetheless, refused, because the subject was unexperienced in touch interaction. Thus the evaluation is explained in the following with 6 participants (the least amount of participants, which ensures counterbalancing), aged from 21 to 26 (mean 23,5 years). All of the regarded probands are familiar with touch interaction and are students respectively researchers or knowledge workers. Three of the participants have already used pen input devices and consider themselves as experienced with pen interaction. Furthermore, just two participants have used a touch device for scientific working purposes, one has used, herefore, the smartphone and another one a tablet computer. All of the participants have already used a computer and pen & paper for scientific working.
Because *active reading* affects any researcher, it is not distinguished between the course of study, so a high range of different courses is taken into consideration:

- Economics (2x)
- Social sciences
- Physics
- Law
- Computer sciences

Results: Platform and Time Efficiency

The time component is an essential aspect, which is mainly investigated also by the hypothesis validation. At first the overall required time for the whole procedure of each system is analyzed. Afterwards the individual hypotheses are regarded and finally, the quality of recalling a concrete document with its emphases is evaluated.

Overall time comparison
The overall time comparison is established through cumulating each task's required time. It gives a first impression about the overall time consumption, which is considered for a short analysis of the overall constructed *active reading* process (see Figure 40). When working with the paper based system, the overall required time is rather widespread, while the digital and hybrid system approach are predominantly equally distributed within each regarded system. This is for example due to different reading behaviors and search strategies, accomplished by the probands, and will be regarded later on in detail. In either way, the hybrid interaction approach is – with respect to time efficiency – the most appropriate system type for *active reading* for the overall constructed workflow, and paper more efficient than the pure digital software solution.
Thus it is at first examined, whether the acquired data is *normal distributed* or not. Due to the *Central Limit Theorem* a normal distribution could be expected to be very close to a normal distribution with a sample of 30 elements [29:132], which is for the conducted study with 6 participants not the case. It is investigated, whether there is a *normal distribution* ϕ or not by using the *Shapiro-Wilk test*, which is considered as appropriate for a sample set less or equal to 2000, in contrast to the *Kolmogorov-Smirnov test*, which is used for greater sample sets [43]. The test of normality for the overall required task time with respect to either system reveals no significances at all, which means that the alternative hypothesis that there is no *normal distribution* is rejected and the *t-test* is accomplished in the following (see Figure 41).
To accomplish the described comparison purposes, a two-sample t-test is performed for *normal distributed data*, else a non-parametric testing is investigated with the *Mann-Whitney U test* [15].
The analysis of variance (ANOVA) is used to compute the means of either possible group attributes and associated measures, due to the *within-subject design*, the approach of *repeated measures ANOVA* is used to analyze the reliability of the data [32]. The *repeated measures analysis of variance (RMANOVA)* reveals that there is no significant difference between

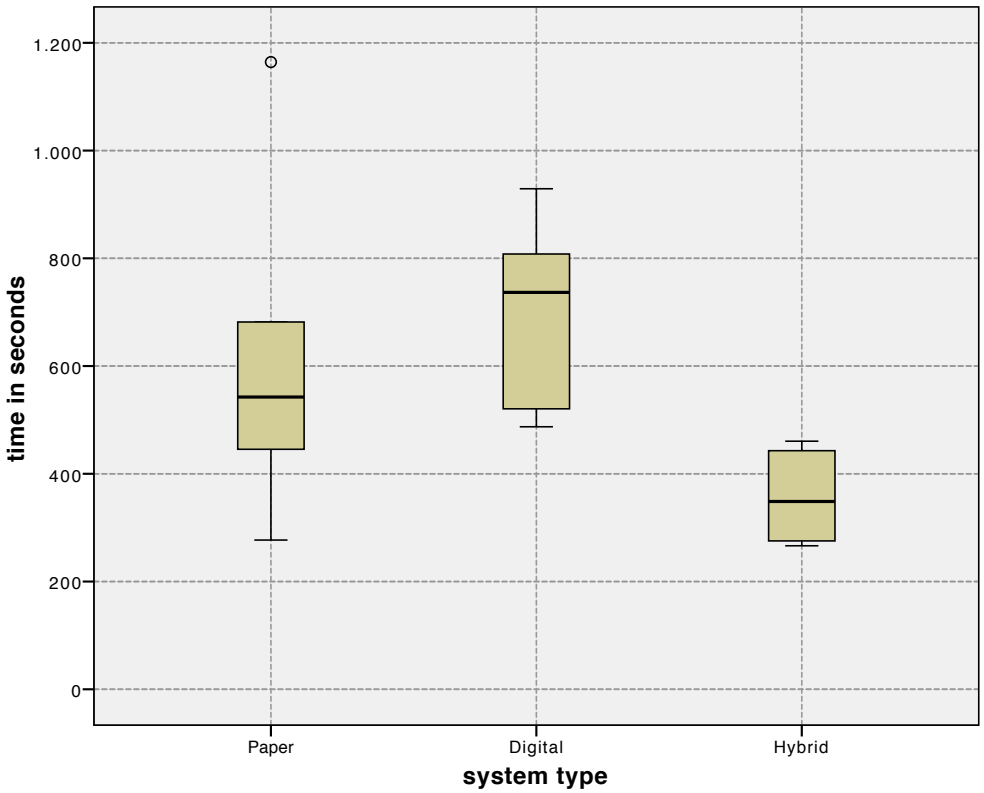


Figure 40: Total time required to solve given tasks, distinguished between system type

the user's experience or vision (see Appendix 6.8). Thus it is assumed that the differences of required time for solving the overall tasks relies on the system type.
In case the underlying data set is not normal distributed, the RMANOVA is not used, it requires the mean to compute the variance. Because the mean is not taken as reference in non-parametric testing, the methodology of the ANOVA differs. Thus, the *Kruskal-Wallis analysis of variance (KW ANOVA)* is used to test for differences in possible groups, which might occur due to differing user attributes (e.g. pen or touch experience) [36:326].
Because independent variables (such as user's experience and vision) are excluded as cause of required time differences, the reason is seen in the independent variable *system type*. Thus, a paired t-test is accomplished among either comparison constellation (*P - H*, *D - H* & *D - P*).
The probability that the system type is responsible for the entire work-

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Paper	,239	6	,200*	,896	6	,350
Digital	,191	6	,200*	,937	6	,636
Hybrid	,226	6	,200*	,874	6	,244

Figure 41: Test of normality regarding the overall required time of each system

flow effectiveness in comparison to another system requires to compute the degree of freedom in a *within-subjects design* as followed [36:321]:

$$df = [\text{number of participants}] - 1 = 6 - 1 = 5$$

The thesis that there is no correlation between the *system type* and the *overall required time* is refused, if the related value of the t-table is exceeded (see Appendix 6.9). Because a confidence interval of 95% is considered, the compared value makes up 2,571. As the *t-value* for the pairwise comparison of $P-H$ and $D-H$ exceed the value of 2 571, both constellations are statistically significant between the two regarded variables (see Figure 42). Regarding the pairwise comparison of D - P (the *pure digital* and *paper based* system) there is no significance ($t = 1{,}323 < 2{,}571 \rightarrow 0{,}243 \geq 0{,}05 \widehat{=} 5\%$), which is not enough evidence that there is enough difference in the mean distribution for the two systems.

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Paper - Hybrid	251,867	238,176	97,235	1,9164	501,82	2,590	5	,049
Pair 2	Digital - Hybrid	346,017	121,583	49,636	218,42	473,61	6,971	5	,001
Pair 3	Digital - Paper	94,1500	174,273	71,147	-88,74	277,04	1,323	5	,243

Figure 42: Paired t-test of overall required time with either system

Regarding the *overall required time* to solve the user's tasks, there is a correlation of the *system's type*, if the system type is the *hybrid* approach. In both pairwise comparisons, the *hybrid* approach enabled the users to

perform the given tasks faster than the other systems did. thus it is thus considered that the *hybrid* approach fastens up the overall workflow of a knowledge worker for *active reading* for the regarded subjects. in the following time efficiency related to the hypotheses are examined to investigate reasons for an appropriate system's design.

1. $\boldsymbol{\xi_1}$ requires as much *time* marking text passages as $\boldsymbol{\xi_2}$

$H_{0,1}$: $\boldsymbol{\xi_1}$ requires as much *time* **marking text passages** as $\boldsymbol{\xi_2}$
$H_{1,1}$: $\boldsymbol{\xi_1}$ requires more or less *time* **marking text passages** than $\boldsymbol{\xi_2}$

Significance Level: $\alpha = 0\ 05$
Degree of freedom: 5
Regarded user tasks: #3,#5,#7
Normal distribution ϕ for: P, D, H
RMANOVA: No significances between other variables and the system

The proof of significance reveals, that there is a significance between the *digital* and *hybrid* interaction approach (see Figure 43). Because the RMANOVA did not reveal any significances between the variables and the investigated systems, it is assumed that the significance is reasoned by the different system's solutions.

Paired Samples Test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Paper - Hybrid	18,70	29,7972	12,165	-12,57	49,97	1,54	5	,185
Pair 2	Digital - Hybrid	37,47	35,4148	14,458	,30113	74,63	2,59	5	,049
Pair 3	Digital - Paper	18,77	35,9661	14,683	-18,98	56,51	1,28	5	,257

Figure 43: Paired t-test of required time with either system for hypothesis 1 related tasks

Regarding the pairwise comparison of the systems, there is no significance, when regarding $P - H$ and $D - P$. The resulting conclusion is a significant difference in the mean distribution of the digital system and the hybrid system, in a pairwise comparison. In the following, a significance will be illustrated with a green bar and an asterisk (*) between both means, which differ significantly (see Figure 44).

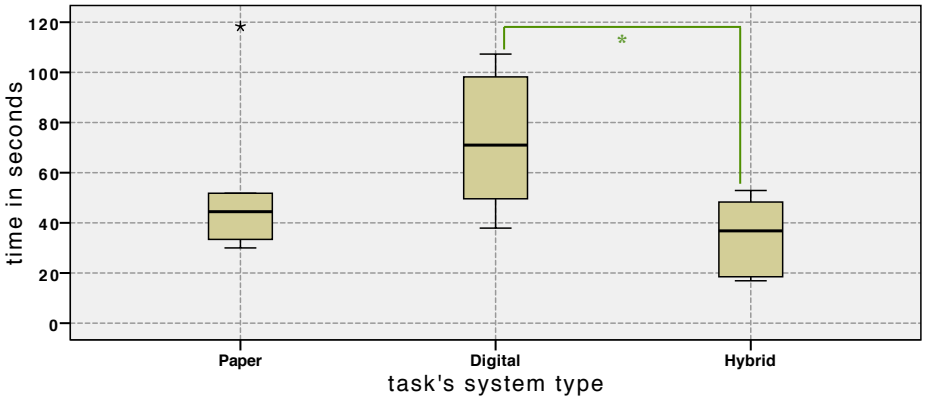


Figure 44: Time required to solve marking related tasks, distinguished between system type; significances of the means are illustrated in green

$H_{0,1}^{HP}$: not rejected $H_{0,1}^{HD}$: rejected $\rightarrow$ $H_{1,1}^{HD}$ assumend: $H > D$ $H_{0,1}^{DP}$: not rejected

Regarding the time component and the quantitative data, the hypothesis $H_{0,1}^{HD}$ is rejected, due to the significance. Thus the alternative hypothesis $H_{1,1}^{HD}$ is assumed and the *digital approach* ($M = 72{,}5; SD = 29{,}26$) significantly less efficient than the *hybrid interaction technique* ($M = 35{,}03; SD = 14{,}86$) for text emphasizing purposes.
A reason for the significant differing of both means is seen in the subjective's comments and behavioral traits. The *pure digital* solution makes use of touch input. The text selection for text emphasizing is then triggered through pan gestures, just as the scrolling process. To switch between either mode, the user has to accomplish a long press gesture and not even move the finger. Slightly most participants had problems investigating this secondary touch, although the setting was in a controlled environment, which did not disturb or interrupt the user when solving the tasks. One participants once required 19 attempts to finally trigger the emphasizing mode and thought that the application crashed. Furthermore, two participants tried to clean the surface of their fingers and the display, because they thought that there are foreign substances between the display and the fingers, which might distract the touch recognition. This specific problem was even more distracting, because users were restricted to emphasize text parts just on the current page (not across multiple pages) and had to proceed with the emphasizing on another page again. In addition, a proband commented after using the *hybrid interaction approach*: "I would like to have such a

pen, it was so cool."[24].
When using the hybrid approach, a subjective complimented the different opportunities to emphasize a text and enjoyed to make use of a vertical line at the text's margin to emphasize the entire text abstract.
Offering different opportunities for text marking and the ability not to switch a current interaction mode for emphasizing relevant text passages is considered as essential for a system supporting *active reading* of digital documents.

2. ξ_1 requires as much *time* annotating text passages as ξ_2

$H_{0,2}$: $\boldsymbol{\xi_1}$ requires as much *time* **annotating text passages** as $\boldsymbol{\xi_2}$
$H_{1,2}$: $\boldsymbol{\xi_1}$ requires more or less *time* **annotating text passages** than $\boldsymbol{\xi_2}$

Significance Level: $\alpha = 0\ 05$
Degree of freedom: 5
Regarded user tasks: #9
Normal distribution ϕ for: P, D, H
RMANOVA: No significances between other variables and the system

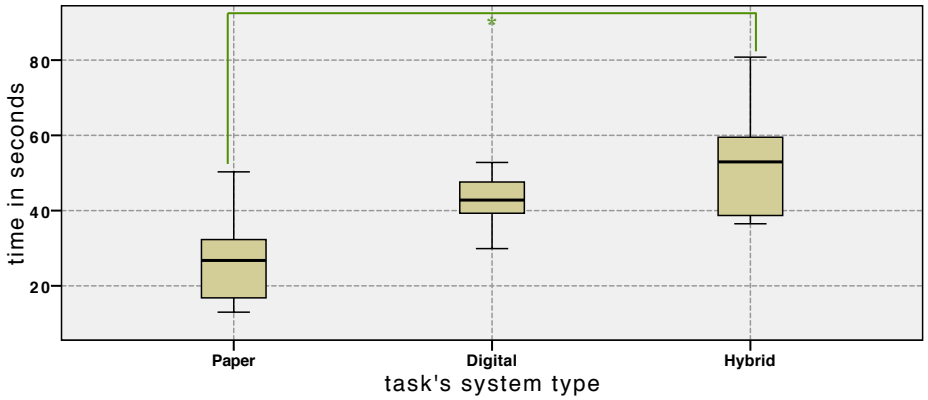


Figure 45: Time required to solve annotation related tasks, distinguished between system type; significances of the means are illustrated in green

The hypothesis $H_{0,2}^{HP}$ is rejected, due to the significance of the pairwise comparison of the *paper based* and *digital* system. The alternative hypothesis $H_{1,2}^{HP}$ is assumed and the *conventional paper based approach* significantly differs from the *hybrid interaction technique* for annotation purposes.

[24] Quote of a participant. Original quote: "Ich will so einen Stift, der war so cool."[Translation was done by the author, T. B.]

$H_{0,2}^{HP}$: rejected $\rightarrow$ $H_{1,2}^{HP}$ assumend: $P > H$
$H_{0,2}^{HD}$: not rejected
$H_{0,2}^{DP}$: not rejected

The mean of the *paper based* technique averages ($M = 27{,}65; SD = 13{,}52$) less than the *hybrid interaction approach* ($M = 53{,}57; SD = 16{,}43$). A reason in this behavior is seen in the required triggering of the annotation mode in the *hybrid interaction* solution. The interaction technique dictates the user to call the annotation mode, by tapping on the emphasized word. Unfortunately, the text's font size is considered as too small for the touch interaction (even with a defined threshold). Furthermore, users expected to call this function with a tap of the pen, as the pen is seen as tool for annotation purposes. A tapping of the pen (with the same or different color of the emphasis of interest) causes a replication of the selected text's emphasis. This replicated emphasis is obviously not experienced by the user, if the color and the emphasis stays the same. A participant mentioned, even being aware of this functionality: "To diminish single words destroys more [of the emphasis' context] than it makes sense."[25].
The users comments and behavior induce that the *annotation mode* as a such is not disruptive for annotating text passages. It rather determines that the cause of action is inconvenient. Users have already proposed implicitly that this specific *annotation mode* requires to be accomplished through a selection process of the pen, by simply tapping the text passage of interest.
Although users had to switch between modes in the digital solution, as there was no opportunity to switch between either tool, no barriers occurred for users when solving the tasks. The explicit mode switching seems to be more understandable to the user.

3. $\boldsymbol{\xi_1}$ requires as much *time* referencing text passages as $\boldsymbol{\xi_2}$

$H_{0,3}$: $\boldsymbol{\xi_1}$ requires as much *time* **referencing text passages** as $\boldsymbol{\xi_2}$
$H_{1,3}$: $\boldsymbol{\xi_1}$ requires more or less *time* **referencing text passages** as $\boldsymbol{\xi_2}$

Significance Level: $\alpha = 0\ 05$
Degree of freedom: 5
Regarded user tasks: #10
Normal distribution ϕ for: P, H
RMANOVA: No significances between other variables and the system
KW ANOVA: No significances between other variables and the system

[25] Quote of a participant. Original quote: "Einzelne Wörter demarkieren macht mehr kaputt [von dem Kontext der Markierung] als es Sinn macht."[Translation was done by the author, T. B.]

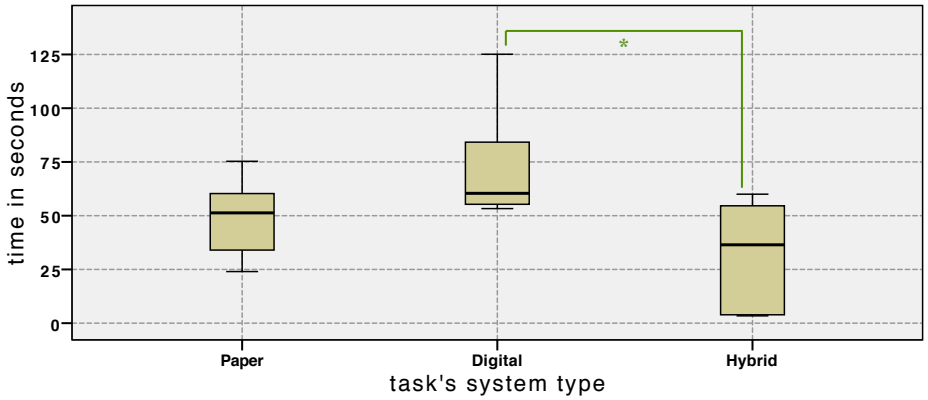


Figure 46: Time required to solve referencing related tasks, distinguished between system type; significances of the means are illustrated in green

The referencing aspect also requires an overview of recently examined documents by the user. Users had to type in a document's title or had to copy and paste the correlated passages for referencing purposes, which took its time. Furthermore, subjects intended to be as precisely as possible with their spelling, because they wanted to be able to retrieve the document later on. In addition, a subject asked, whether there is an opportunity to open recent documents, because the proband was not aware anymore of former documents, which should have been opened. This also reflects the task's solution time of the *digital system* ($M = 73{,}12; SD = 27{,}9$) in comparison to *paper* ($M = 49{,}37; SD = 18{,}33$) and the *hybrid approach* ($M = 32{,}47; SD = 24{,}5$).

$\mathrm{H}_{0,3}^{HP}$: not rejected $\mathrm{H}_{0,3}^{HD}$: rejected $\rightarrow \mathrm{H}_{1,3}^{HD}$ assumend: $H > D$ $\mathrm{H}_{0,3}^{DP}$: not rejected

Inefficiency aspects regarding referencing text passages of the *digital approach* differed significantly from the *hybrid solution*. The null hypotheses $\mathrm{H}_{0,3}^{HD}$ is thus rejected and it is assumed that the referencing tasks are solved with the *hybrid's solution* significantly more efficient, regarding $\mathrm{H}_{1,3}^{HD}$.

5. ξ_1 requires as much *time* retrieving documents passages as ξ_2

$H_{0,5}$: $\boldsymbol{\xi_1}$ requires as much *time* **retrieving documents** as $\boldsymbol{\xi_2}$
$H_{1,5}$: $\boldsymbol{\xi_1}$ requires more or less *time* **retrieving documents** as $\boldsymbol{\xi_2}$

Significance Level: $\alpha = 0\ 05$
Degree of freedom: 5
Normal distribution ϕ for: D, H
Regarded user tasks: #1, #6
RMANOVA: No significances between other variables and the system
KW ANOVA: No significances between other variables and the system

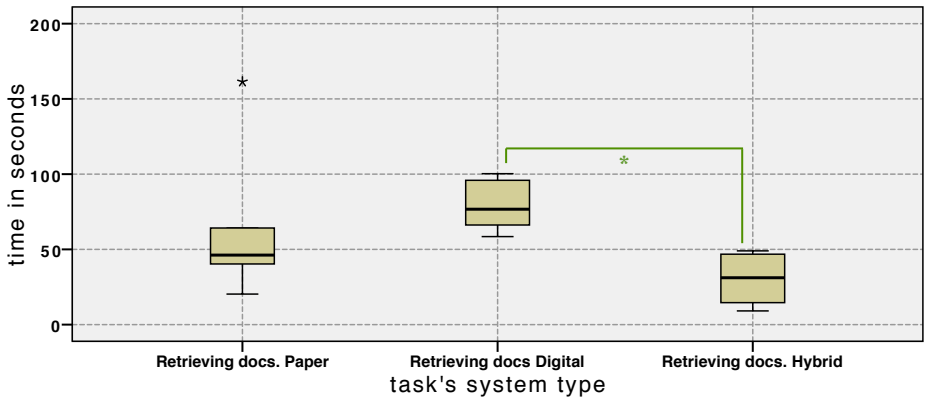


Figure 47: Time required to solve document retrieving related tasks, distinguished between system type; significances of the means are illustrated in green

Multiple document's management is part of retrieving documents. Users had to open documents and retrieve literature referenced in a document of interest. There are several observations made for all of the three approaches.
The *paper based approach* made use of stapling the documents. Users were forced to turn their pages over and folded the document at the page of interest. They were thus enabled to fast retrieve a document of interest, without being required to skim through the document, to identify the document of interest. Furthermore, they could easily navigate back to the cover page, read the title and author and go back to their page of origin. Although the *conventional approach* seems to offer a lot of advantages, users got confused when there were two documents of the same author. The document referencing by some subjects was accomplished with the author, not with the document's title, they thus got distracted by the alleged wrong document's title at first.

The *digital application* forced the user to always navigate back in the document's overview, which took several seconds of animation. During this navigation step, some users forgot the document's title of interest and had to head back to remind themselves of the title. Furthermore, users faced the problem that they lost their navigation path across regarded documents and were not aware of their document of origin anymore.
Linked references are illustrated as blue text in and between documents by the hybrid approach. Nevertheless, a subject was looking for a bibliography in a document. Thus it is assumed that users require both functionalities. On the one hand immediate access through linking, on the other hand the opportunity to acquire additional meta-information about a reference in a well-known bibliography chapter.

$H_{0,5}^{HP}$: not rejected $H_{0,5}^{HD}$: rejected $\rightarrow$ $H_{1,5}^{HD}$ assumend: $H > D$ $H_{0,5}^{DP}$: not rejected

The required time due to navigational barriers of the *digital approach* differed significantly from the *hybrid solution*. The *hybrid approach* enabled users to perform and solve their tasks faster ($M = 30{,}3; SD = 17{,}68$) than the *pure digital solution* did ($M = 79{,}05; SD = 16{,}57$). Thus the null hypothesis $H_{0,5}^{HD}$ is rejected and it is assumed that retrieving text documents is significantly more efficient with the approach of the *hybrid solution*.

6. $\boldsymbol{\xi_1}$ requires as much *time* locating chapters as $\boldsymbol{\xi_2}$

$H_{0,6}$: $\boldsymbol{\xi_1}$ requires as much *time* **locating chapters** as $\boldsymbol{\xi_2}$ $H_{1,6}$: $\boldsymbol{\xi_1}$ requires more or less *time* **locating chapters** as $\boldsymbol{\xi_2}$ Significance Level: $\alpha = 0\ 05$ Degree of freedom: 5 Regarded user tasks: #2 Normal distribution ϕ for: P, D, H RMANOVA: No significances between other variables and the system

Regarding the within document navigation, users had no problems at all of retrieving a certain chapter of interest or to navigate to it. Neither the *digital approach*, with which the tasks were performed the fastest ($M = 10{,}95; SD = 5{,}66$), nor the *paper based approach* ($M = 12{,}33; SD = 4{,}27$) and the *hybrid technique* ($M = 13{,}57; SD = 5{,}44$) differ significantly. Nevertheless, it is observed that the digital approach to offer a chapter overview enabled the users to perform the fastest (regarding the mean).
Because there is no significancy observed at all, neither null hypothesis is

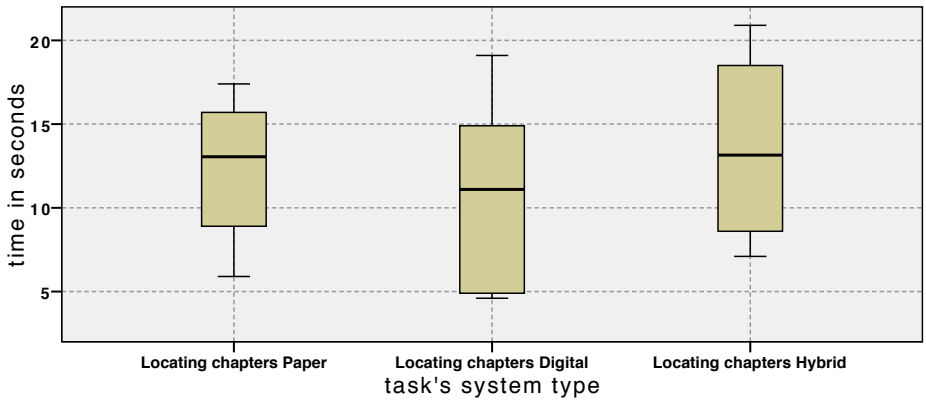


Figure 48: Time required to solve chapter locating related tasks, distinguished between system type; no significances of the means at all

rejected and there is just a trend extrapolation possible, where the *digital approach* seems to offer the most adequate approach with a chapter overview, but this is not proven in detail by the participants.

$H_{0,6}^{HP}$: not rejected $H_{0,6}^{HD}$: not rejected $H_{0,6}^{DP}$: not rejected

8. ξ_1 requires as much *time* locating words as ξ_2

$H_{0,8}$: $\boldsymbol{\xi_1}$ requires as much *time* **locating words** as $\boldsymbol{\xi_2}$ $H_{1,8}$: $\boldsymbol{\xi_1}$ requires more or less *time* **locating words** as $\boldsymbol{\xi_2}$
Significance Level: $\alpha = 0\ 05$ Degree of freedom: 5 Regarded user tasks: #4, #8 Normal distribution ϕ for: P, D, H RMANOVA: No significances between other variables and the system

There are areas of improvement for the *paper based* approach, due to its physical constraints. Subjects made use of different skimming strategies. Some participants were scanning line by line, while making use of the pen as ruler to not shift between the lines by accident. Other users scanned the text not by the word itself, but rather for its context and prominent text parts (numbers or references with brackets). In either way, participants required significantly more time looking for certain words of interest ($M = 340{,}7; SD = 201{,}13$) than they did with the *hybrid* ($M = 95{,}62; SD = 53{,}36$).

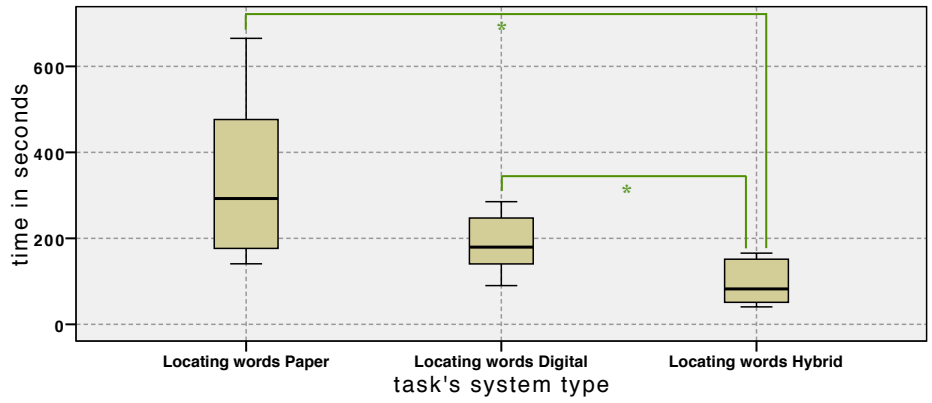


Figure 49: Time required to solve word locating related tasks, distinguished between system type; significances of the means are illustrated in green

The *digital approach* offered the users functionalities, such as auto suggestion of occurring terms and full-text search. Still, users had problems to locate words in the same document, search results were not highlighted during the entire search process, which was mentioned as irritating by subjects. A proband mentioned designated after several attempts: ”Why doesn’t it [the

application] emphasize it [the search term]?"[26].Furthermore, the full-text search of the digital solution was just accomplished in the current document. The search term had to be reentered when a new document was opened, in case the search was accomplished across documents. These difficulties are seen as possible occasion for the significant more time consuming task solution of the users with the *digital approach* ($M = 187{,}07; SD = 72{,}56$) than with the *hybrid interaction technique* ($M = 95{,}62; SD = 53{,}36$).

$H_{0,8}^{HP}$: rejected $\rightarrow$ $H_{1,8}^{HD}$ assumend: $H > P$ $H_{0,8}^{HD}$: rejected $\rightarrow$ $H_{1,8}^{HD}$ assumend: $H > D$ $H_{0,8}^{DP}$: not rejected

Although users required the most time with *conventional paper* for locating words, some techniques performed by the user could be adapted to even enhance the *hybrid* approach. For example, a reading ruler could help the users to not shift between lines in the mobile context.
Regarding the comparison between the *pure digital* system and the *hybrid* one, users desired full-text search, although this functionality was not explicitly required for solving the tasks. Altogether, the *hybrid approach* is considered as most efficient for locating words across documents. Users did especially commend the search result visualization, with the amount of upcoming and previous search terms. Nevertheless, there is area for improvement, regarding offered functionalities.

9. ξ_1 requires as much *time* retrieving emphasized passages as ξ_2

$H_{0,9}$: $\boldsymbol{\xi_1}$ requires as much *time* **retrieving emphasized passages** as $\boldsymbol{\xi_2}$ $H_{1,9}$: $\boldsymbol{\xi_1}$ requires more or less *time* **retrieving emphasized passages** as $\boldsymbol{\xi_2}$
Significance Level: $\alpha = 0\ 05$ Degree of freedom: 2, due to (2 populations, each 3 participants) Regarded user tasks: #11, #12, #13 Normal distribution ϕ for: P, D, H (both populations) RMANOVA: Significances between touch interaction experience and the system

The RMANOVA reveals a significance with respect to touch experience, users have.It is thus assumed that the overall participants are not of one population, because the results differ with respect to their touch experience. In the following, these populations are regarded separately with respect to

[26] Quote of a participant. Original quote: "Warum markiert der [das Programm] das [das Suchwort] denn nicht?"[Translation was done by the author, T. B.]

either experience. Two populations derive, each containing three subjects. At first the population, which is rather experienced in touch interaction is regarded.

Population 1 – rather experienced in touch interaction
There exist three significances between the mean execution time of the systems. This means that there is a significance between all pairwise comparisons, which results in the rejection of all related null hypotheses. The *paper based* approach is considered as the most efficient one ($M = 72{,}2; SD = 24{,}81$). Users made use of turning over a page and kept their last page and text passage of interest on the front. Subjects were thus easier able to recognize the emphases they made within the corresponding documents.
In contrast to the *paper based approach*, the *digital* one required the user to always navigate to the documents overview and orient themselves in the documents' visualization. Unfortunately, participants mentioned that they are not aware of what document they had opened before and which they did not ($M = 332{,}03; SD = 116{,}05$).
In the *hybrid approach*, some users also faced the problem that they did not know the document's title anymore. Nevertheless, additionally functionalities offered, helped users to navigate to the text passage of interest. For example, the circles of each document in the documents' overview, which illustrate the total amount of emphases and the corresponding color-coding, enabled users to orient themselves in the documents' overview and to perform significantly better ($M = 105{,}83; SD = 24{,}12$) than they did with the *digital approach*.

The distribution of *required time measures* reflects a clear hierarchy of time efficiency among the three systems. The *digital approach* is considered as least efficient for retrieving emphasized text parts. The most efficient solution is the *paper based behavior* followed by the *hybrid technique*.
These measures of *population 1* are in the following compared to the measures of *population 2* to illustrate the differences between both groups, which rely on the user's touch experience.

Population 1
$H_{0,9}^{HP}$: rejected $\rightarrow$ $H_{1,9}^{HD}$ assumend: $P > H$
$H_{0,9}^{HD}$: rejected $\rightarrow$ $H_{1,9}^{HD}$ assumend: $H > D$
$H_{0,9}^{DP}$: rejected $\rightarrow$ $H_{1,9}^{HD}$ assumend: $P > D$

Population 2 – experienced in touch interaction

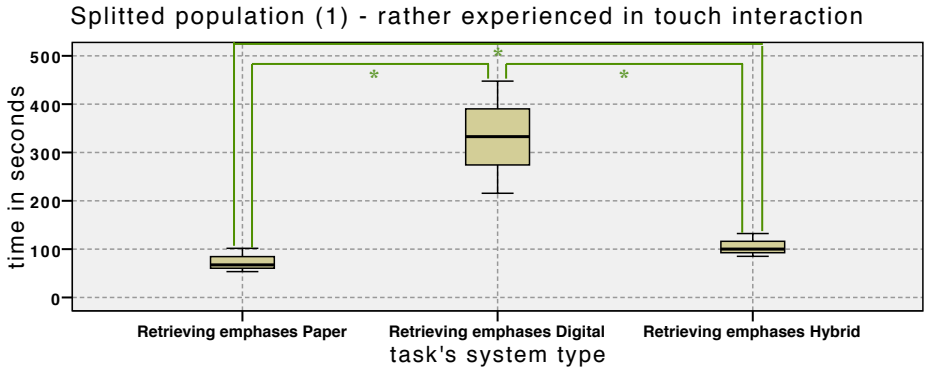


Figure 50: Population 1: Time required for retrieving emphases related tasks, distinguished between system type; significances of the means are illustrated in green

Population 2 comprises subjects, which are more touch experienced than those of *population 1*. Based on measures, a significant difference of the means derived from the comparison of the task solution time of the *digital approach* ($M = 143{,}7; SD = 42{,}95$) and the *hybrid system* ($M = 87{,}2; SD = 45{,}62$). This significance is also related to the capacity of remembering regarding a document's title. Subjects were hardly able to recall the concrete document of interest and inspected the document's overview and other single documents at first.

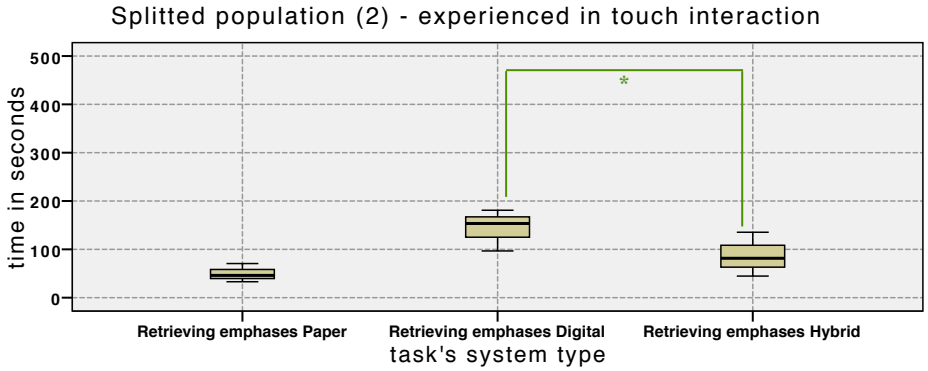


Figure 51: Population 2: Time required for retrieving emphases related tasks, distinguished between system type; significances of the means are illustrated in green

Due to the means significant difference, the null hypothesis $H_{0,9}^{HD}$ is rejected and – just as *population 1* – the alternative hypothesis assumed that users could retrieve emphases in documents more efficient with the *hybrid solution* than with the *digital one*.

Population 2
$H_{0,9}^{HP}$: not rejected
$H_{0,9}^{HD}$: rejected $\rightarrow$ $H_{1,9}^{HD}$ assumend: $H > D$
$H_{0,9}^{DP}$: not rejected

For comparison purposes, the required means and the corresponding standard deviations are listed in the following (see Table 15):

System type	Population 1	Population 2
Paper	$M = 72{,}2$ $SD = 24{,}81$	$M = 49{,}9$ $SD = 19{,}09$
Digital	$M = 332{,}03$ $SD = 116{,}05$	$M = 143{,}7$ $SD = 42{,}95$
Hybrid	$M = 105{,}83$ $SD = 24{,}12$	$M = 87{,}2$ $SD = 45{,}62$

Table 15: Comparison of required mean time of population 1 and population 2 for retrieving emphases

It is noticeable that *population 2* - the more touch experienced user population - solved the tasks faster than *population 1* with all systems. It seams that the touch experience is correlated to the overall performance of the users, furthermore the required time with the *digital approach* is decreased by more than the half. It is assumed that touch experienced people require less cognitive workload for solving the *emphases retrieving related* tasks, which has to be proven in future[27].
All in all, just the null hypothesis for the comparison of the *digital* and *hybrid* approach $H_{0,9}^{HD}$ is rejected, as it was rejected in both groups. So, the following statement is made:

$H_{0,9}^{HP}$: not rejected
$H_{0,9}^{HD}$: rejected $\rightarrow$ $H_{1,9}^{HD}$ assumend: $H > D$
$H_{0,9}^{DP}$: not rejected

[27] This is out of the study's scope. The study aims to identify an appropriate design solution for defining design guidelines.

10. $\boldsymbol{\xi_1}$ requires as much *documents* retrieving emphasized passages as $\boldsymbol{\xi_2}$

In addition to the task completion time, an additional measurement was made. It was counted how many documents a user did look through to finally retrieve the emphasized text passage. It aims to measure the quality of capacity for remembering the examined documents with respect to executed emphases from former user tasks.

$H_{0,10}$: $\boldsymbol{\xi_1}$ requires to scan as much *documents* **retrieving emphasized passages** as $\boldsymbol{\xi_2}$
$H_{1,10}$: $\boldsymbol{\xi_1}$ requires to scan more or less *documents* **retrieving emphasized passages** as $\boldsymbol{\xi_2}$

Significance Level: $\alpha = 0\ 05$
Degree of freedom: 2
Measure: Amount of scanned documents
Normal distribution ϕ for: P, D, H
RMANOVA: No significances between other variables and the system

Although the average amount of documents per task differs, there is no significance at all observed. Nevertheless, users were more successful in retrieving the document and text passage of interest with the *paper based* approach than with either *digital based* solution. The users simply had a better overview of the documents. If they required to examine the most recent ones, they simply lifted their current documents and the remaining documents appeared below in there documents stack on the page where they left the document.
A similar solution is tried to realize with the *hybrid* approach, where different mechanisms, such as the breadcrumbs or the color coded annotation circles are offered. The document was even opened where the user quit it. Nevertheless, users were more successful in remembering the documents in the physical world. Thus, neither null-hypotheses is rejected.

$H_{0,10}^{HP}$: not rejected
$H_{0,10}^{HD}$: not rejected
$H_{0,10}^{DP}$: not rejected

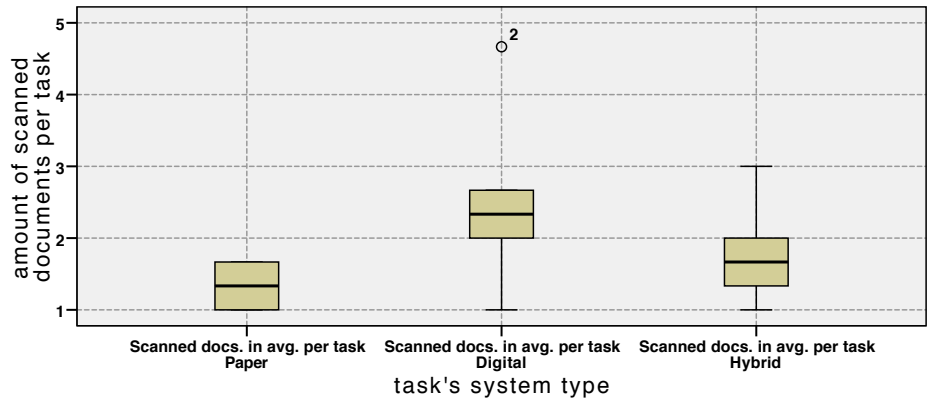


Figure 52: Average amount of scanned documents for retrieving a formerly made emphasized text passage by the users

Results: Task Suitability and Subjective Workload

The task solution time is considered as indicator for efficiency of a user's task. With respect to the score of a user's workload, indicated through the TLX, the specific effect is regarded as cause of decreased task suitability. For gaining an insight regarding the cause of an inappropriate solution approach, different factors of the user's demands are inspected.

4. ξ_1 is equal in *user satisfaction* rating as ξ_2 regarding annotating

$H_{0,4}$: $\boldsymbol{\xi_1}$ is equal in *user satisfaction* rating as $\boldsymbol{\xi_2}$ regarding **annotating**
$H_{1,4}$: $\boldsymbol{\xi_1}$ is better or worse in *user satisfaction* rating as $\boldsymbol{\xi_2}$ regarding **annotating**

Significance Level: $\alpha = 0\ 05$
Degree of freedom: 5
Normal distribution ϕ: factor *Mental demand* and *Performance* are not normal distributed for H, these factors are compared separately.
RMANOVA: No significances between other variables and the system
KW ANOVA: No significances between other variables and the system

Regarding the users workload assessment, the *hybrid approach* was the most appropriate in comparison to either system (see Appendix 6.10). The pairwise comparison of either system's TLX with focus on annotating reveals almost no significances. Just the mean of the sum of all factors for the *digital approach* ($M = 33{,}75; SD = 12{,}87$) differs significantly from the *hybrid solution* one ($M = 21{,}92; SD = 5{,}87$).
An interesting aspect is the trend of a lower physical demand for the *hybrid*

approach, compared to the *digital* one. Both solutions require the user to hold the tablet computer and perform certain gestures. In fact, the *hybrid approach* even necessitates the additional pen as tool. Nevertheless, the *hybrid approach* is considered as more appropriate. It is assumed that there is a correlation of the required task solution time and the system type. Users had to carry the device even longer, if they required more time.
The overall results reveal that there is a trend for the *hybrid approach* to be the most appropriate system to work with. This is confirmed by the rejection of the null-hypothesis $H_{0,4}^{HD}$. However, there is no universally valid evidence for the *hybrid approach* to be the most appropriate one. This could be just partially proven.

$H_{0,4}^{HP}$: not rejected $H_{0,4}^{HD}$: rejected $\rightarrow$ $H_{1,4}^{HD}$ assumend: $H > D$ $H_{0,4}^{DP}$: not rejected

7. $\boldsymbol{\xi_1}$ is equal in *user satisfaction* rating as $\boldsymbol{\xi_2}$ regarding (cross-document) navigation

$H_{0,7}$: $\boldsymbol{\xi_1}$ is equal in *user satisfaction* rating as $\boldsymbol{\xi_2}$ regarding **(cross-document) navigation** $H_{1,7}$: $\boldsymbol{\xi_1}$ is better or worse in *user satisfaction* rating as $\boldsymbol{\xi_2}$ regarding **(cross-document) navigation**
Significance Level: $\alpha = 0\ 05$ Degree of freedom: 5 Normal distribution ϕ: factor *Frustration* is not normal distributed for D & H, this factor is compared separately. RMANOVA: No significances between other variables and the system KW ANOVA: No significances between other variables and the system

The *conventional paper based technique* demanded significantly more physical workload ($M = 54{,}83; SD = 21{,}7$) than the *digital* ($M = 14{,}17; SD = 11{,}14$) and the *hybrid* ($M = 14{,}17; SD = 15{,}3$) one did.
Although the within-document navigation benefited from the possibility to staple pages and fold them, the *paper approach* encompassed 83 pages in total for all five documents. This required the user to manage a stack of paper, which results in a hindered physical performance in the mobile context. This barrier is represented by the significant difference between *paper* and either *digital based* approach (see Appendix 6.11).
Although there are no overall significant differences among either system, partial significant differences are detected, regarding the comparison of $P - H$ and $P - D$ and their pairwise compared physical demand.

$H_{0,7}^{HP}$: not rejected, but $H \succeq P$
$H_{0,7}^{HD}$: not rejected
$H_{0,7}^{DP}$: not rejected, but $D \succeq P$

11. $\boldsymbol{\xi_1}$ is equal in *user satisfaction* rating as $\boldsymbol{\xi_2}$ regarding (cross-document) search

$H_{0,11}$: $\boldsymbol{\xi_1}$ is equal in *user satisfaction* rating as $\boldsymbol{\xi_2}$ regarding **(cross-document) search**
$H_{1,11}$: $\boldsymbol{\xi_1}$ is better or worse in *user satisfaction* rating as $\boldsymbol{\xi_2}$ regarding **(cross-document) search**

Significance Level: $\alpha = 0\ 05$
Degree of freedom: 5
Normal distribution ϕ: factor *Effort* is not normal distributed for P, this factor is compared separately.
RMANOVA: No significances between other variables and the system
KW ANOVA: No significances between other variables and the system

The estimated workload due to *paper* is statistically significant compared to the *digital* and *hybrid application* (see Appendix 6.12). The only aspect where there is no significance at all is the *performance* factor. Although the quantitative time related data reveals a statistically significance between the systems, the subjective assessment does not differ significantly. This relies on different searching strategies, which lead to a greater standard deviation of this specific factor. Furthermore, participants mentioned that they expected *paper* for not being the most appropriate solution for text search, which might have tempted the subjects to assess the subjective workload with biases.
Nevertheless, the subjective workload of *paper based working* in sum ($M = 58{,}75; SD = 17{,}61$) is perceived as more exhausting than the *digital* ($M = 29{,}17; SD = 9{,}86$) or *hybrid solution* ($M = 24{,}24; SD = 22{,}69$).

$H_{0,11}^{HP}$: rejected $\rightarrow$ $H_{1,11}^{HP}$ assumend: $H > P$
$H_{0,11}^{HD}$: not rejected
$H_{0,11}^{DP}$: rejected $\rightarrow$ $H_{1,11}^{DP}$ assumend: $D > P$

Results: Function Rating

Significance Level: $\alpha = 0\ 05$
Degree of freedom: 5 (total)
Normal distribution ϕ for: all functions
One way ANOVA: No significances between other variables and the functionalities

Altogether the system's functionalities are rated above average (see Figure 53). Still, there is area for improvement. Regarding the navigational aspect, users were mostly satisfied. Two users would have liked to have a full-text search, although it was not required for solving the tasks. They are simply used to it and would have liked to have such a search functionality that looks through the entire data collection.

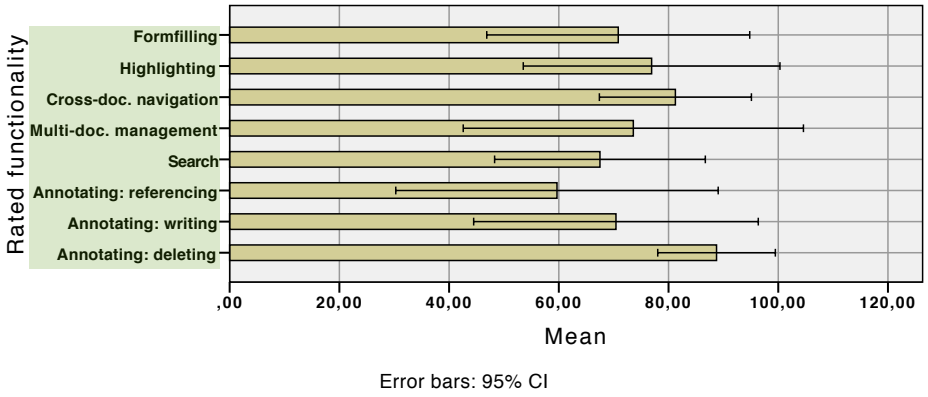


Figure 53: Users' rating of the usefulness of different system functionalities ranging from 0 (few satisfied) to 100 (very satisfied); statistically significant functionality ratings marked green

Regarding a computed one-sample t-test, all functionality's ratings are significant, which induces that most of the offered functionalities are considered as satisfying and helpful for scientific working purposes, because all means are higher than the half of 50 (see Table 16).

Rated function	N	Mean	Std. Deviation	Std. Error Mean
Formfilling	6	70,83	22,84	9,32
Highlighting	6	76,92	22,29	9,1
Cross-doc. navigation	6	81,25	13,21	5,39
Multi-doc. management	6	73,58	29,55	12,06
Search	6	67,5	18,3	7,47
Annotating: referencing	6	59,67	28,0	11,43
Annotating: writing	6	70,42	24,72	10,09
Annotating: deleting	6	88,75	10,22	4,17

Table 16: One-sample t-test of user's rated functionalities

Results: System Limitations

Users were asked to rate how much they were affected by system limitations and constraints. The ratings range from 0 (little affected) to 100 (strongly affected). The lower the value, the less affected the system constraints are considered and the fewer it is assumed that a specific constraint distracts the users.

Significance Level: $\alpha = 0\ 05$ Degree of freedom: 5 (total) Normal distribution ϕ for: all functions, excluding *Text visualization* One way ANOVA: One significance between other variables and the limitations: *experience in scientific working with tablet computers* and the *palm rejection* constraint

To test for significant differences, the *one-sample t-test* is used for a normal distributed data. As equivalent for the *one-paired t-test* the *Wilcoxon Rank-Sum test* is used for the nonparametric data set [23:130]. Here, the sample data is compared to the functionality's mean to determine a significant difference. The computed *Wilcoxon Rank-Sum test* showed no significant difference between the sample data and the computed mean, thus *Text visualization* is statistically significant.
Due to the result of the *One way ANOVA*, the population is split into two sub-populations. *Population 1* comprises five users, the residual one subject is assigned to *population 2*, which is experienced in scientific working with tablet computers. For *population 1*, there is a significance rating for *palm rejection* ($M = 19{,}5; SD = 7{,}98$), which indicates that users had almost no problems at all. The participant of *population 2* rated the functionality with 62,5. Because there is just one subject, no standard deviation is computed. It is assumable that the subject is used to palm rejection, which is just enabled in the *annotation mode*, because users shall be able to interact bimanually when editing the document.
Still, bimanual interaction was limited to lifting the tablet, while interacting with the other hand. Users did not make use of both hands to interact with the documents at all. In fact, it was mentioned that users have to hold the tablet somehow, which is in the long range exhausting.

The system limitations are mostly rated as less distracting for *scientific working* purposes. The absence of statistically significance for the *display's size* is explained by the high variation of the user's rating, ranging from the least minimum value 0 to the maximum value 100. Some subjects preferred to work with paper and other participants simply expected a tablet

computer to be even more lightweight and smaller for better portability.
An aspect of focus is the pen with its related limitations. Derived from the physical world where text markers provide a different functionality from a common pencil, the synergy of both to the single pen solution of the *hybrid approach* irritated some participants. Users simply asked for different pen modes. Furthermore, the pen's accuracy was criticized, which should be even more improved in the future. In this context especially the stroke recognition of the pen is in focus, which requires a greater set of gesture trainings, to improve gesture recognition based on sample data.

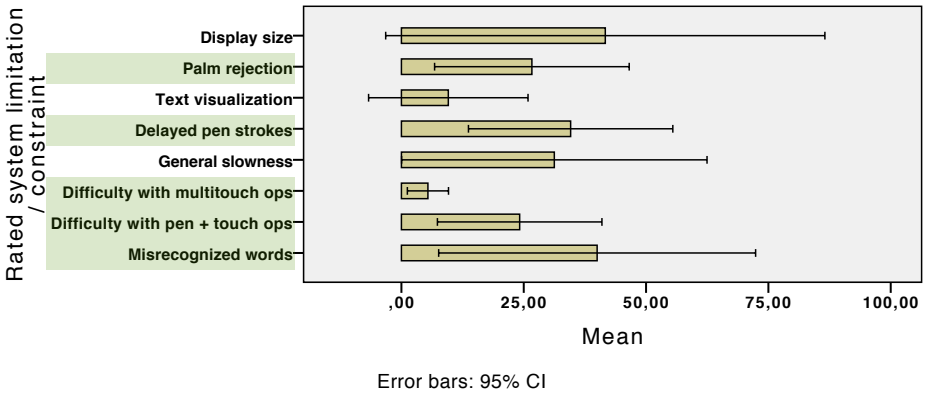


Figure 54: Users' rating regarding the hardware and software limitations and how users felt affected by them, ranging from 0 (little affected) to 100 (strongly affected); statistically significant constraint ratings marked green

Qualitative Analysis of Hybrid User Interaction Behavior

In addition to the summative evaluation based on time requirements and the NASA TLX form sheets, a log file is used to track a user's interaction behavior with the *hybrid interaction approach*. The gained data is neither comparable to *conventional paper* nor to the *digital solution*, because there is no such a log implemented, still the collected data is illustrated for reasons of completeness.
Both interaction behaviors have been logged and are illustrated in two separate visualizations: pen interaction and touch interaction.

Pen interaction

The *pen interaction's* log data provide information regarding an inappropriate application's behavior related to the pen (see Appendix 6.13). Some users expected to trigger the *annotation mode* by tapping onto the emphasis rather with the pen than with the finger. For consistency aspects, this approach is comprehensible, although the preliminary gesture study revealed that users prefer to select text parts of interest by touch.

A further challenge is the pen stroke recognition, either the system was not able to recognize the given pen strokes as pen gesture or the user was not aware of it to happen. In the illustrated data set, a user did simply not recognize that both emphases had already been referenced and tried to reference both again.

Another aspect taken into account is the awareness of the current color. Users were offered the ability to recognize, which color they already have selected with the pen. This color is consistent over documents and has to be changed by tapping with the pen on the sample board. Nevertheless, users did tap on the sample board and did select the same color once again. Subjects mentioned that this goes faster than taking a look at the visualization on the tablet computer. Furthermore, it is correlated to the physical behavior, where users actively select a color pen of interest.

An interesting aspect is the user's focus when interacting with the pen. Most of the interaction did not occur close to the displays border. Users dragged text parts of interest rather to the center of the screen, and emphasized the text. Furthermore, annotations were made more centralized. It is assumed that this behavior correlates between the physical trait, where users lay down their palm for more accurate hand writing. Users can use the tablets margin to lay down their palm and write with the pen rather centralized than at the border. A further cause could be the focus point of the user. Text passages of interest are rather drawn in the center of the display and not retained at the displays border, to keep the text's context in focus.

Altogether the causes of this interaction behavior require further investigation in detail, which would prove or disprove the assumptions made. Nevertheless, the measurements give a detailed insight for identifying an intuitive and most appropriate interaction design solution.

Touch interaction

The performed *touch interaction* reveals the frequency of use of different user controls (see Appendix 6.14). The frequency of the views itself is not comparable among themselves, because the tasks are not balanced throughout the different controls. Nevertheless, it is observable that this specific

subject made use of the document's overview to fasten up navigation or retrieve certain text parts of interest. In contrast to the within-document navigation, the breadcrumb bar is mainly untouched by the user, in fact most of the cross-document navigation was handled by the overall documents overview, not with making use of the breadcrumb navigation approach. Either the navigation was not diffused enough for the user to make use of it, the navigation approach itself was misunderstood or the user was simply not aware of this technique. Most users stack to the conventional navigation to keep a document and its correlated meta-information in mind to retrieve the document once again. Actually, the participants were introduced with the breadcrumb's functionality, but did mostly overlook the navigation aid. It is assumed that this functionality has to be focussed more prominently, the functionality requires further improvement. A user mentioned that it could be implemented as a common tab-bar of web-browsers, where different tabs would cover different topics and each tab would comprise its own navigation path.
Furthermore, it is observed that users did hardly make use of the *annotations scrollview* or the rearrangement of emphases in the *annotation mode*, also the reformatting of the document's view was ignored. These specific functionalities were not required to solve the tasks, nevertheless, users were told that these functionalities exist and they could have made use of them. The lack of making use of these functionalities reveals that users did not require them for navigating, annotating or text search. Still, these functionalities are considered as useful for *operation* purposes, when building a mental model of a certain topic or domain.

5.4 Discussion

The developed application, the applied interaction techniques and the conducted experiments are an approach to get an insight in the usefulness of a bimodal and bimanual user interaction approach for *active reading* in the mobile context. For example, the overall time required to solve the tasks was significantly better than with former approaches, which results in an improved efficiency for knowledge workers' work processes.
The amount of probands represents a small random sample of knowledge workers. Thus, the representativeness of the gained insight based on quantitative data is questioned regarding it's external validity[28]. Still, an explo-

[28] "*External validity* asks the question of *generalizability*: To what population, setting, treatment variables,[!sic] and measurement variables can this effect be generalized?"[8:28]

rative trend analysis based on these findings is investigated for a system's redesign. In a second step this could be broadened with investigating even more participants with the same or similar study design and evaluation approach, in case the data reliability should be granted and compared.
Regarding the third research question, which is about qualitative usability testing with respect to function and limitation rating, the recommended amount of evaluators ranging from three to five is even extended [39]. The gained qualitative insights, also regarding statements of improvement, are thus taken seriously. The results, are now used to develop short design guidelines for a system, which supports *active reading* on tablet computers in the mobile context, also inspired by efficiency lacks based on the evaluated system's task efficiency.

Annotating

1. $\boldsymbol{\xi_1}$ requires as much *time* **marking text passages** as $\boldsymbol{\xi_2}$
2. $\boldsymbol{\xi_1}$ requires as much *time* **annotating text passages** as $\boldsymbol{\xi_2}$
3. $\boldsymbol{\xi_1}$ requires as much *time* **referencing text passages** as $\boldsymbol{\xi_2}$
4. $\boldsymbol{\xi_1}$ is equal in *user satisfaction* rating as $\boldsymbol{\xi_2}$ regarding **annotating**

Aspect	Hypothesis	H^{HP}	H^{HD}	H^{DP}
Annotation	1		$H > D$	
	2	$P > H$		
	3		$H > D$	
	4		$H > D$	

Table 17: Summarization of annotation related hypotheses

Although users rated their individual workload as better with the *hybrid interaction technique*, they had different remarks to even improve the system (see Table 17). The pen is used as synergetic tool for inking and gestures. Sometimes the gestures were not recognized as the users intended it to be, thus they had to redraw the strokes again. A user simply mentioned to appreciate an additional mode, where the pen's mode could be switched between writing and performing gestures. These modes could be offered on the left margin of the tablet computer, for example, to spatially separate this input area from the sample board (see Appendix 6.15).

A further observation were the problems when users wanted to select a single word for annotating. It is appreciated to enter the *annotation mode* by selecting the annotation with a tap performed with the pen, not by touch input.
Especially regarding the task efficiency the *hybrid approach* enabled users to perform better than with the *digital approach*. Nevertheless, the note-taking functionality requires further improvement. An eraser was desired for example, because pen gestures that were recognized wrong could not be deleted anymore. In addition, user required to draw the strokes even faster and desired a more accurate gesture identification, as the system's limitation ranking reveals.

Navigation

5. $\boldsymbol{\xi_1}$ requires as much *time* **retrieving documents** as $\boldsymbol{\xi_2}$
6. $\boldsymbol{\xi_1}$ requires as much *time* **locating chapters** as $\boldsymbol{\xi_2}$
7. $\boldsymbol{\xi_1}$ is equal in *user satisfaction* rating as $\boldsymbol{\xi_2}$ regarding **(cross-document) navigation**

Aspect	Hypothesis	H^{HP}	H^{HD}	H^{DP}
Navigation	5		$H > D$	
	6			
	7	$H \succeq P$		$D \succeq P$

Table 18: Summarization of navigation related hypotheses

Navigation tasks, asked by Matulic & Norrie, differed in it's solution opportunities from the task model of this study. Here, tasks were formulated specifically to avoid users to make use of functions for random navigation and rather use sequential navigation functionalities, such as the overview or common document scrolling [37]. Matulic & Norrie revealed that their tabletop solution was slightly worse regarding the efficiency performance of *navigation* tasks than the digital counterpart on a desktop computer, caused by different approaches by the users.
For reasons of comparison, this study made use of a system, running on the same device, the *pure digital approach*. Regarding the subjective impressions of participants, there is no significance regarding the user satisfaction

between both systems at all, nonetheless, the required time to retrieve documents was significantly worse than the *hybrid solution*. Still, there is area for improvement. A participant mentioned to like keeping the bibliography, well-known from the physical world. Furthermore, a combination of both approaches could be offered and a document's references additionally provided in a separate section of the documents overview.
For better cross-document navigation tabs could be offered, were different user histories could be stored, derived from well-known web browser functionalities.
Regarding within-document navigation, a user simply skimmed over a chapter, because the navigation was performed too fast. An appropriate within-document navigation is thus required, which enables users to be aware of the current chapter, as the digital solution did. The chapter overview requires to be more prominent for the user, while not requiring too much loading time for rendering a chapter when it is loaded, as it did in the *pure digital approach*,

Text search

8. $\boldsymbol{\xi_1}$ requires as much *time* **locating words** as $\boldsymbol{\xi_2}$
9. $\boldsymbol{\xi_1}$ requires as much *time* **retrieving emphasized passages** as $\boldsymbol{\xi_2}$
10. $\boldsymbol{\xi_1}$ requires as much *documents* **retrieving emphasized passages** as $\boldsymbol{\xi_2}$
11. $\boldsymbol{\xi_1}$ is equal in *user satisfaction* rating as $\boldsymbol{\xi_2}$ regarding **(cross-document) text search**

Aspect	Hypothesis	H^{HP}	H^{HD}	H^{DP}
Text search	8	$H > P$	$H > D$	
	9	P1: $P > H$ P2: -	P1: $H > D$ P2: $H > D$	P1: $P > D$ P2: -
	10			
	11	$H > P$		$D > P$

Table 19: Summarization of text search related hypotheses

Text search was initiated as *query by example* for the *hybrid* approach. Users could select a word by long-pressing the text part of interest and lift up the finger on the specific word of interest. Still, users mentioned to

require full-text search, as it is well-known from solutions based on *digital content*. The full-text search provided by the *digital counterpart* additionally offered search term suggestions, which were appreciated by some participants. Nonetheless, the search field should be closely positioned to the keyboard, with a preview of suggested search terms, so users cannot oversee this offered functionality, when focussing the keyboard for search term typing.

The user study has furthermore revealed the capacity for remembering among the participants, regarding formerly used documents and emphases made within these documents. Users coped with different barriers when trying to retrieve a formerly made emphasis. For example, they were not aware of the document's title anymore, had to retrieve the document in a new location and opened the wrong one. Another aspect was the concrete position of the text of interest in the correct document. The overall search functionality could be enriched by a search, offering within-document results (content results) and document results, which meta-information match to the search request, to enhance the browsing and retrieving aspect.

The breadcrumb navigation was intended to help users with cross-document navigation and recalling the documents of interest. Furthermore, each document provides a visualization with the amount of annotations made and the annotations distribution, regarding their color coding. Still, further mechanisms have to be implemented, which might help users to identify documents faster, based on it's content, annotations but also it's document relations [4].

As a final step of text excerpts and annotations, the knowledge worker's results still have to be integrated in the knowledge generation process. The annotation area could be extended to an overall notebook, where emphases, references and text are displayed as a whole and can be exported to a mental map work sheet. Of course, different advantages, such as back and forward linking to retrieve the emphasis' document and text of origin is required, still this might be very useful to make a step to the *operating* process with gained insight from documents.

6 Conclusion

The origin of this elaboration is the knowledge about increasing availability of digital media items, requiring adequate and integrated interaction opportunities for related operators. Current operational procedures are correlated to media discontinuity due to identified lacks of users' well-known behavioral traits, which are not adopted to digital content. Users have to cope with either digital or physical document properties, which are mostly reduced to either advantages.
Regarding the understanding of Adler (1941), the knowledge generation process, based on *active reading* and working with documents, requires a reader to set a document's content into context and fuse different sources [2:34]. Text parts of interest are commonly duplicated and extracted to notebooks, rearranged and restructured. These information artifacts are either tightly coupled as annotation within the document of origin and loosely coupled to a reconstruction or vice versa. This duplication of information artifacts, semantic and weak back-linking to it's sources and the extraction process itself are considered as inappropriate, which requires users to make use of both digital and physical advantages.
With the goal of generating an adequate system's interaction design, allowing users to interact in a well-known way and also taking their requirements into consideration, different user studies were accomplished. These investigations aimed to generate a system design, consistent over user requirements, interaction approaches and the increasing relevance of portability and mobility. This system was implemented with technology, which was at this time state of the art and was evaluated regarding its efficiency and user satisfaction, compared to other current systems.
The results reveal a certain efficiency improvement in comparison to the state of the art digital counterpart and certain challenges for digital based system solutions in comparison to conventional paper based working. Still, the developed system and it's hybrid interaction approach the system design's assets and are used to utter additional design requirements for an even better working environment.

RBI makes use of well-known treatments and physical attributes, which eases the complexity and offers different tools and related solution approaches. Still, some challenges have to be overcome. The integration of attributes from different pens of the physical world in one pen with different attributes in the digital world irritated some participants. The fine line between reality and expressive power, efficiency and ergonomics has to be kept in mind, even if additional interaction steps would be necessary [28]. An advantage could also be to color the interaction pen in the corresponding color, which was out of scope for the exploratory gesture interaction user study, to help users to identify their current color selection.
In future, the identified system design could be used to enhance the overall individual and group work process of knowledge workers. As a first step, this requires more powerful and accurate hardware[29], which offers required functionalities out of the box, without the necessity of pen calibration. As a second step, import and export functionalities are required for the work process integration, such as *Office Open XML*[30] or *OpenDocument Text*[31]. Additionally, the browsing and operation process require to be considered with appropriate interaction technique and interfaces to recommender systems or search engines, while offering large displays to visualize large information spaces. Finally, the document structure requires has to be to support hyperlinking or additional media content, such as images or videos.
All the identified enhancements are part of every days processes of knowledge workers and require extensive research as a single, which could then be combined to big picture.

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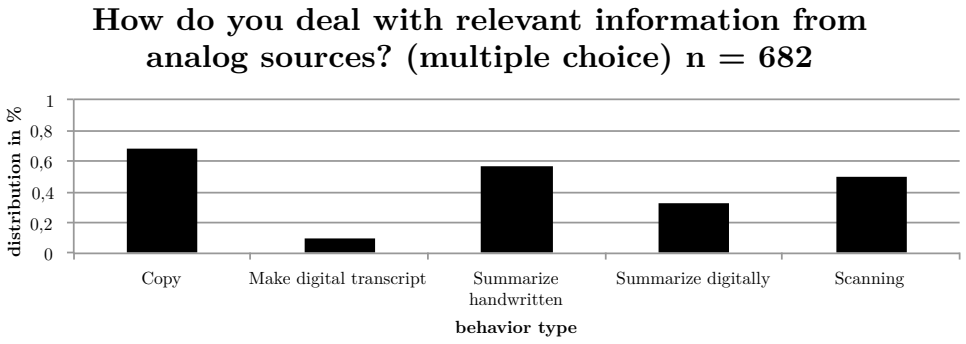
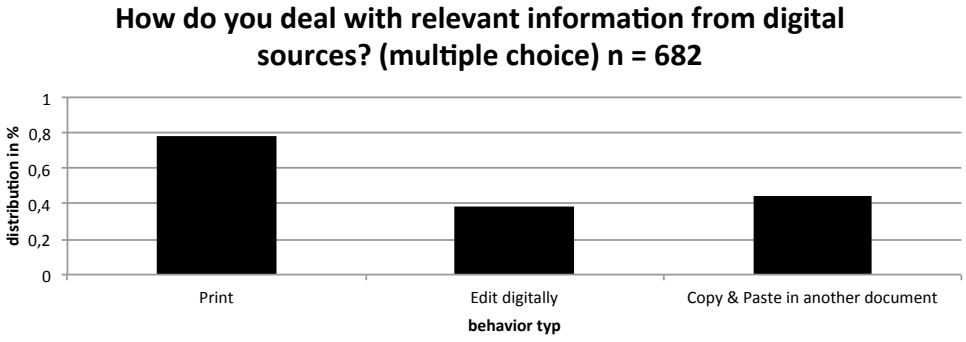
Appendix

1. Media Discontinuity in Scientific Working Process





2. Questionnaire of an explorative user study about scientific working behavior

Fragebogen zum Thema Gruppenarbeitssituationen

Hinweis: Zu allen offenen Fragen genügen Stichpunkte

1. Welchem Fachbereich (inkl. Semester) gehört Ihr an und zu welchem Thema sollt/ wollt Ihr referieren/ präsentieren/ lernen?

2. Was soll das Endergebnis Eurer Arbeit sein? (Hausarbeit, Bericht, Präsentation, Unterrichtsgestaltung, Examensvorbereitung etc.)

3. Wo trefft Ihr Euch normalerweise? (Wenn an der Universität, dann bitte spezifizieren)

4. Eine Frage nebenbei: Wie viele von Euch sind Smartphone-Besitzer?

5. Welche Hilfsmittel & Materialien benutzt Ihr normalerweise für die Gruppenarbeit? (Bücher, Papers, eBooks, Papier & Stift, Laptop etc.)

6. Wie oft habt Ihr Euch bereits getroffen (inkl. heute) und wie oft plant Ihr Euch noch zu treffen? (Abschätzung kumuliert mit Erfahrung)

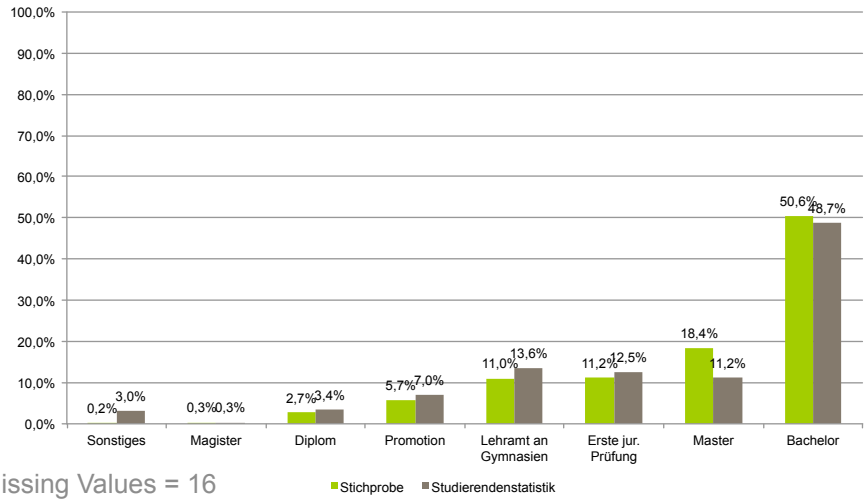
7. Wie lang ist Eure Zusammenarbeit?

8. Was sind die Hauptgründe Eurer Treffen? (Arbeitsteilung, Kommunikation, kollaboratives Erarbeiten/ Schreiben/ Zusammenstellen, Erklären, Diskutieren etc.)

9. Stellt Euch einen magischen Apparat vor an den Ihr einen Wunsch äußern könnt, der Euch die Gruppenarbeit erleichtert und diese unterstützt: welcher Wunsch wäre dies? („fertiges Endergebnis“ und „eingeimpftes Wissen“ zählt nicht als Antwort)

3. Requirements analysis: distribution of course of studies participants

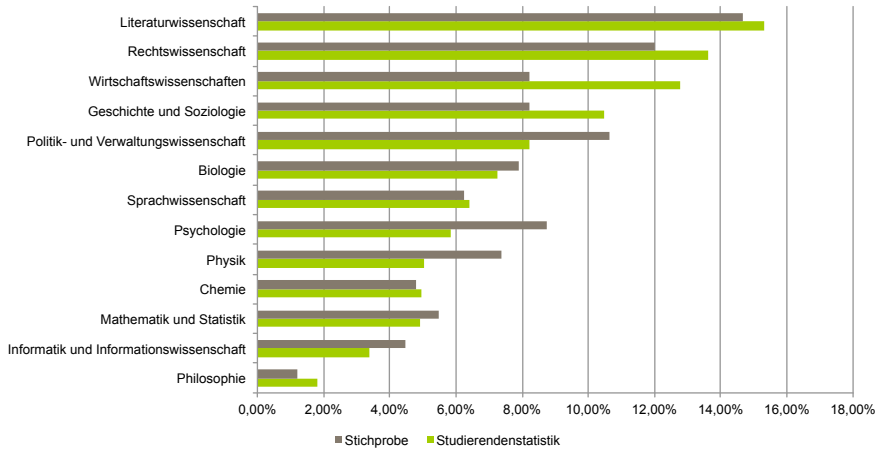
Vgl. Verteilung **Abschlussziele** – Studierendenstatistik WS 2011/2012



Missing Values = 16
N = 583 (Std m. Angabe)
N + MV = 599

4. Requirements analysis: distribution of graduation degree of participants

Vgl. Verteilung **Fachbereich** – Studierendenstatistik WS 2011/2012



N = 583 (Studierende mit Angabe)
Missing Values = 16
N + MV = 599

5.Relative frequency of positive aspects of tools for researchers

Classification	Code	Pen & Paper	Computer	Tablet / Smartphone	Σ
Notes, annotating	N	0,41	0,02	0,20	0,635
Use it anywhere, for anything	FI	0,13	0,02	0,30	0,448
Search	S	0,00	0,31	0,06	0,361
Flexible ordering	SK	0,23	0,06	0,02	0,307
Self-Management	RS	0,12	0,02	0,09	0,230
Dictionaires, Thesaurus	TH	0,00	0,05	0,15	0,193
(Multiple) Documents management	AS	0,00	0,13	0,02	0,153
(Documents) Overview	Ü	0,06	0,06	0,02	0,132
Format & Export	M	0,02	0,08	0,02	0,123
Cross-Referencing	CR	0,06	0,06	0,00	0,111
Communication	KOM	0,00	0,04	0,06	0,099
Learning	L	0,09	0,01	0,00	0,092
Safety & Persistency	SI	0,01	0,02	0,04	0,072
Formula	FO	0,06	0,01	0,00	0,066
Analysis	ANA	0,00	0,07	0,00	0,066
Readability	LES	0,03	0,04	0,00	0,065
First exploration	ES	0,05	0,00	0,00	0,057
Convention (it is expected)	KON	0,00	0,03	0,02	0,052
Complex articles	KA	0,03	0,02	0,00	0,051
Multiple Doc/Pages	MD	0,03	0,00	0,02	0,047
Second step / Further processing	ZS	0,00	0,04	0,00	0,041
Computing	RECH	0,00	0,03	0,00	0,031
Formatting	F	0,01	0,01	0,00	0,028
haptics	H	0,02	0,00	0,00	0,025
Focus / No distraction	FA	0,02	0,00	0,00	0,024
Health	GES	0,01	0,01	0,00	0,022
Picture / Screenshot	FOTO	0,00	0,00	0,02	0,021
Index cards / learn sheets	KAR	0,02	0,00	0,00	0,021
Intuitive	INT	0,01	0,01	0,00	0,020
Reproducibility	REPR	0,00	0,02	0,00	0,018
Text processing	TV	0,00	0,02	0,00	0,018
Transfer / Digitze	DPR	0,00	0,01	0,00	0,015
Export	EX	0,00	0,01	0,00	0,013
Analogous Sources	ANG	0,01	0,00	0,00	0,013
Static workplace	DIV	0,00	0,01	0,00	0,012
Print	PR	0,00	0,01	0,00	0,012
Synchronization	SYNC	0,00	0,01	0,00	0,012
eco friendliness	UMWELT	0,00	0,01	0,00	0,007
No paper stacks	KP	0,00	0,01	0,00	0,006
Individual handwriting	IN	0,00	0,00	0,00	0,005
No auto correction / abbreviations	KAA	0,00	0,00	0,00	0,005
Translation	ÜB	0,00	0,00	0,00	0,003
Crossing out	DHL	0,00	0,00	0,00	0,002
Cannot write into books	NA	0,00	0,00	0,00	0,002
Short articles	DKA	0,00	0,00	0,00	0,001
Space saving	PL	0,00	0,00	0,00	0,001
Quality	Q	0,00	0,00	0,00	0,001

6. Perl script to extract pen data

```
1  open(MYOUTFILE, ">pen_stream.txt");
2  open(MYINPUTFILE, "<Debug_stream.txt");
3  $i=0;
4
5  $penDown="\[ViewController PenDownEvent:]";
6  $penMove="\[ViewController PenMoveEvent:]";
7  $penUp="\[ViewController PenUpEvent:]";
8
9  while(<MYINPUTFILE>)
10 {
11     # Good practice to store $_ value because
12     # subsequent operations may change it.
13     my($line) = $_;
14
15     # Good practice to always strip the trailing
16     # newline from the line.
17     chomp($line);
18
19     $line =~ $regex1;
20     $line =~ s/^.*---\s{.*$//gm;
21     $line =~ s/^.*:\s{/{/gm;
22     if ($line =~ m/^.*$penDown,{.*$/m)
23     {
24         $line =~ s/}/, 1/gm;
25         $line =~ s/^.*$penDown,{//gm;
26     }
27     elsif ($line =~ m/^.*$penMove,{.*$/m)
28     {
29         $line =~ s/}/, 2/gm;
30         $line =~ s/^.*$penMove,{//gm;
31     }
32     elsif ($line =~ m/^.*$penUp,{.*$/m)
33     {
34         $line =~ s/}/, 3/gm;
35         $line =~ s/^.*$penUp,{//gm;
36     }
37     else
38     {
```

```
39          $line =~ s/.*//gm;
40      }
41
42      if (length($line) != 0)
43      {
44          $line =~ s/ /\t/gm;
45          # Print the line to the file
46          print MYOUTFILE "$line\n";
47          #print STDOUT "$line\n";
48      }
49  }
50
51  close (MYOUTFILE);
```

7. Perl script to extract touch data

```
1  open(MYOUTFILE, ">touch_stream.txt");
2  open(MYINPUTFILE, "<Debug_stream.txt");
3  $i=0;
4
5  $touchDown="UITouchPhaseBegan";
6  $touchMove="UITouchPhaseMoved";
7  $touchHold="UITouchPhaseStationary";
8  $touchUp="UITouchPhaseEnded";
9
10 $regex1="s/^((?!{\d+(\.\d+)?,\d+(\.\d+)?}).)*$//gm";
11
12
13 while(<MYINPUTFILE>)
14 {
15     # Good practice to store $_ value because
16     # subsequent operations may change it.
17     my($line) = $_;
18     # Good practice to always strip the trailing
19     # newline from the line.
20     chomp($line);
21
22     if ($line =~ m/^.*$touchDown.*{.*$/m)
23     {
24         $line =~ s/}$/, 1/gm;
25         $line =~ s/^.*$touchDown.*?{.*}.*?{//gm;
26     }
27     elsif ($line =~ m/^.*$touchMove.*{.*$/m)
28     {
29         $line =~ s/}$/, 2/gm;
30         $line =~ s/^.*$touchMove.*?{.*}.*?{//gm;
31     }
32     elsif ($line =~ m/^.*$touchHold.*{.*$/m)
33     {
34         $line =~ s/}$/, 2/gm;
35         $line =~ s/^.*$touchHold.*?{.*}.*?{//gm;
36     }
37     elsif ($line =~ m/^.*$touchUp.*{.*$/m)
38     {
```

```
39          $line =~ s/}$/, 3/gm;
40          $line =~ s/^.*$touchUp.*?{.*}.*?{//gm;
41      }
42      else
43      {
44          $line =~ s/.*//gm;
45      }
46      if (length($line) != 0)
47      {
48          $line =~ s/ /\t/gm;
49          # Print the line to the file
50          print MYOUTFILE "$line\n";
51      }
52  }
53
54  close (MYOUTFILE);
```

8. Repeated measurement ANOVA - total task time

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
totalTime	Pillai's Trace	,989	45,665[b]	2,000	1,000	,104
	Wilks' Lambda	,011	45,665[b]	2,000	1,000	,104
	Hotelling's Trace	91,329	45,665[b]	2,000	1,000	,104
	Roy's Largest Root	91,329	45,665[b]	2,000	1,000	,104
totalTime * Sehhilfe	Pillai's Trace	,000	.[b]	,000	,000	.
	Wilks' Lambda	1,000	.[b]	,000	1,500	.
	Hotelling's Trace	,000	.[b]	,000	2,000	.
	Roy's Largest Root	,000	,000[b]	2,000	,000	.
totalTime * Experience	Pillai's Trace	,889	3,994[b]	2,000	1,000	,334
	Wilks' Lambda	,111	3,994[b]	2,000	1,000	,334
	Hotelling's Trace	7,988	3,994[b]	2,000	1,000	,334
	Roy's Largest Root	7,988	3,994[b]	2,000	1,000	,334
totalTime * PenExp	Pillai's Trace	,623	,827[b]	2,000	1,000	,614
	Wilks' Lambda	,377	,827[b]	2,000	1,000	,614
	Hotelling's Trace	1,654	,827[b]	2,000	1,000	,614
	Roy's Largest Root	1,654	,827[b]	2,000	1,000	,614
totalTime * Sehhilfe * Experience	Pillai's Trace	,000	.[b]	,000	,000	.
	Wilks' Lambda	1,000	.[b]	,000	1,500	.
	Hotelling's Trace	,000	.[b]	,000	2,000	.
	Roy's Largest Root	,000	,000[b]	2,000	,000	.
totalTime * Sehhilfe * PenExp	Pillai's Trace	,000	.[b]	,000	,000	.
	Wilks' Lambda	1,000	.[b]	,000	1,500	.
	Hotelling's Trace	,000	.[b]	,000	2,000	.
	Roy's Largest Root	,000	,000[b]	2,000	,000	.
totalTime * Experience * PenExp	Pillai's Trace	,000	.[b]	,000	,000	.
	Wilks' Lambda	1,000	.[b]	,000	1,500	.
	Hotelling's Trace	,000	.[b]	,000	2,000	.
	Roy's Largest Root	,000	,000[b]	2,000	,000	.
totalTime * Sehhilfe * Experience * PenExp	Pillai's Trace	,000	.[b]	,000	,000	.
	Wilks' Lambda	1,000	.[b]	,000	1,500	.
	Hotelling's Trace	,000	.[b]	,000	2,000	.
	Roy's Largest Root	,000	,000[b]	2,000	,000	.

a. Design: Intercept + Sehhilfe + Experience + PenExp + Sehhilfe * Experience + Sehhilfe * PenExp + Experience * PenExp + Sehhilfe * Experience * PenExp
Within Subjects Design: totalTime

b. Exact statistic

9. t-table

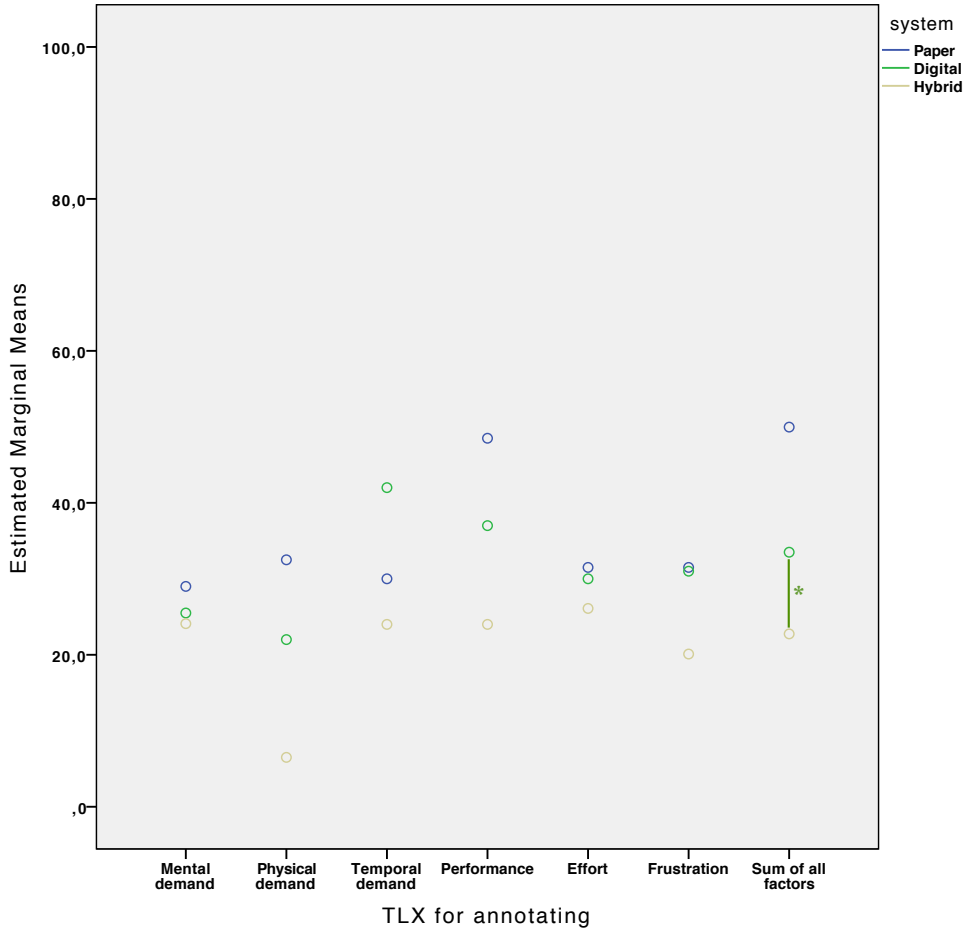
t Table

cum. prob	$t_{.50}$	$t_{.75}$	$t_{.80}$	$t_{.85}$	$t_{.90}$	$t_{.95}$	$t_{.975}$	$t_{.99}$	$t_{.995}$	$t_{.999}$	$t_{.9995}$
one-tail	0.50	0.25	0.20	0.15	0.10	0.05	0.025	0.01	0.005	0.001	0.0005
two-tails	1.00	0.50	0.40	0.30	0.20	0.10	0.05	0.02	0.01	0.002	0.001
df											
1	0.000	1.000	1.376	1.963	3.078	6.314	12.71	31.82	63.66	318.31	636.62
2	0.000	0.816	1.061	1.386	1.886	2.920	4.303	6.965	9.925	22.327	31.599
3	0.000	0.765	0.978	1.250	1.638	2.353	3.182	4.541	5.841	10.215	12.924
4	0.000	0.741	0.941	1.190	1.533	2.132	2.776	3.747	4.604	7.173	8.610
5	0.000	0.727	0.920	1.156	1.476	2.015	2.571	3.365	4.032	5.893	6.869
6	0.000	0.718	0.906	1.134	1.440	1.943	2.447	3.143	3.707	5.208	5.959
7	0.000	0.711	0.896	1.119	1.415	1.895	2.365	2.998	3.499	4.785	5.408
8	0.000	0.706	0.889	1.108	1.397	1.860	2.306	2.896	3.355	4.501	5.041
9	0.000	0.703	0.883	1.100	1.383	1.833	2.262	2.821	3.250	4.297	4.781
10	0.000	0.700	0.879	1.093	1.372	1.812	2.228	2.764	3.169	4.144	4.587
11	0.000	0.697	0.876	1.088	1.363	1.796	2.201	2.718	3.106	4.025	4.437
12	0.000	0.695	0.873	1.083	1.356	1.782	2.179	2.681	3.055	3.930	4.318
13	0.000	0.694	0.870	1.079	1.350	1.771	2.160	2.650	3.012	3.852	4.221
14	0.000	0.692	0.868	1.076	1.345	1.761	2.145	2.624	2.977	3.787	4.140
15	0.000	0.691	0.866	1.074	1.341	1.753	2.131	2.602	2.947	3.733	4.073
16	0.000	0.690	0.865	1.071	1.337	1.746	2.120	2.583	2.921	3.686	4.015
17	0.000	0.689	0.863	1.069	1.333	1.740	2.110	2.567	2.898	3.646	3.965
18	0.000	0.688	0.862	1.067	1.330	1.734	2.101	2.552	2.878	3.610	3.922
19	0.000	0.688	0.861	1.066	1.328	1.729	2.093	2.539	2.861	3.579	3.883
20	0.000	0.687	0.860	1.064	1.325	1.725	2.086	2.528	2.845	3.552	3.850
21	0.000	0.686	0.859	1.063	1.323	1.721	2.080	2.518	2.831	3.527	3.819
22	0.000	0.686	0.858	1.061	1.321	1.717	2.074	2.508	2.819	3.505	3.792
23	0.000	0.685	0.858	1.060	1.319	1.714	2.069	2.500	2.807	3.485	3.768
24	0.000	0.685	0.857	1.059	1.318	1.711	2.064	2.492	2.797	3.467	3.745
25	0.000	0.684	0.856	1.058	1.316	1.708	2.060	2.485	2.787	3.450	3.725
26	0.000	0.684	0.856	1.058	1.315	1.706	2.056	2.479	2.779	3.435	3.707
27	0.000	0.684	0.855	1.057	1.314	1.703	2.052	2.473	2.771	3.421	3.690
28	0.000	0.683	0.855	1.056	1.313	1.701	2.048	2.467	2.763	3.408	3.674
29	0.000	0.683	0.854	1.055	1.311	1.699	2.045	2.462	2.756	3.396	3.659
30	0.000	0.683	0.854	1.055	1.310	1.697	2.042	2.457	2.750	3.385	3.646
40	0.000	0.681	0.851	1.050	1.303	1.684	2.021	2.423	2.704	3.307	3.551
60	0.000	0.679	0.848	1.045	1.296	1.671	2.000	2.390	2.660	3.232	3.460
80	0.000	0.678	0.846	1.043	1.292	1.664	1.990	2.374	2.639	3.195	3.416
100	0.000	0.677	0.845	1.042	1.290	1.660	1.984	2.364	2.626	3.174	3.390
1000	0.000	0.675	0.842	1.037	1.282	1.646	1.962	2.330	2.581	3.098	3.300
z	0.000	0.674	0.842	1.036	1.282	1.645	1.960	2.326	2.576	3.090	3.291
	0%	50%	60%	70%	80%	90%	95%	98%	99%	99.8%	99.9%
	Confidence Level										

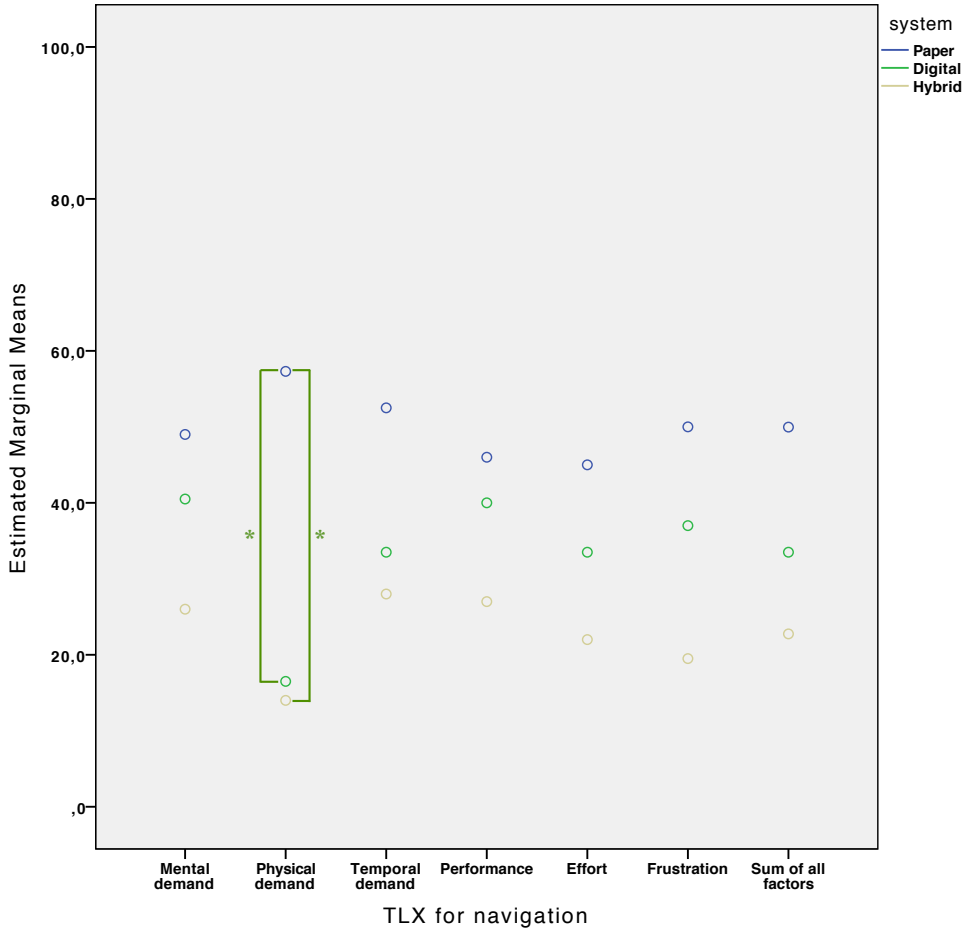
t-table.xls 7/14/2007

Source: http://www.sjsu.edu/faculty/gerstman/StatPrimer/t-table.pdf, seen June 2013

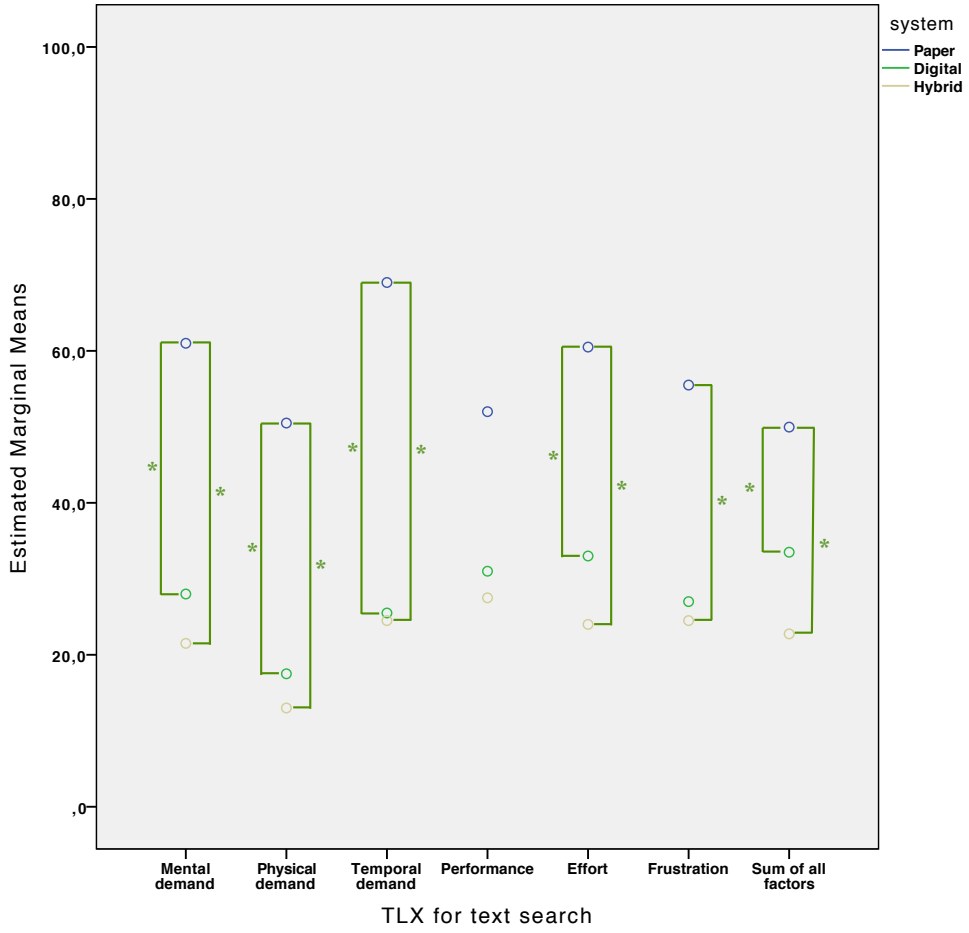
10. Plot of subjective workload for annotation tasks



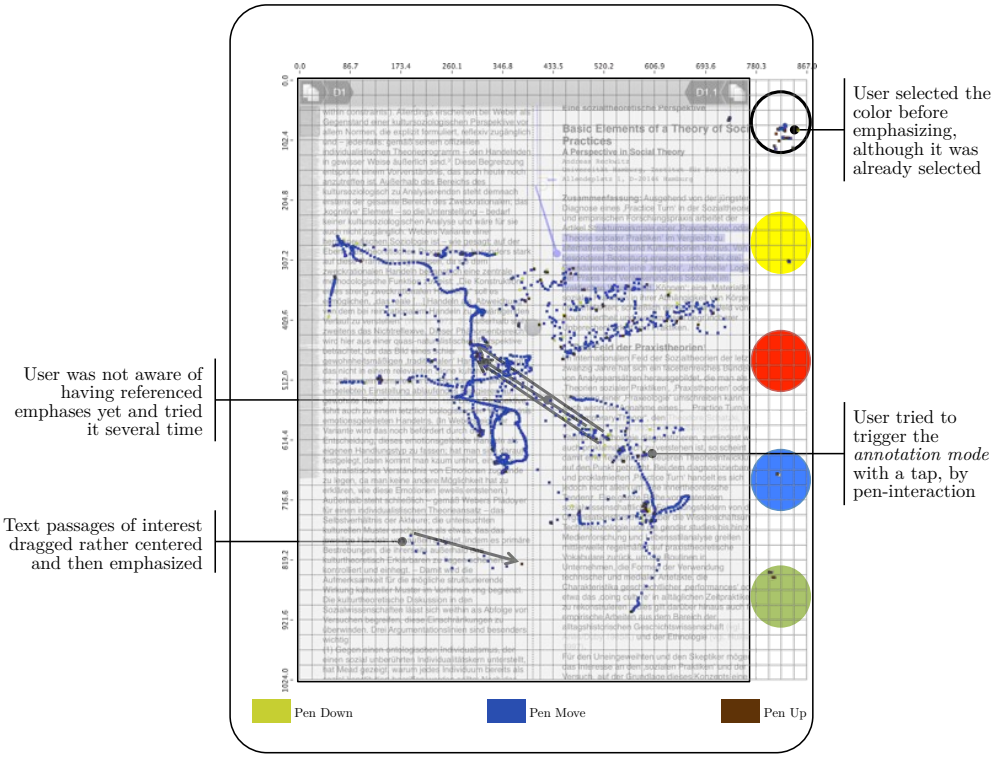
11. Plot of subjective workload for navigation tasks



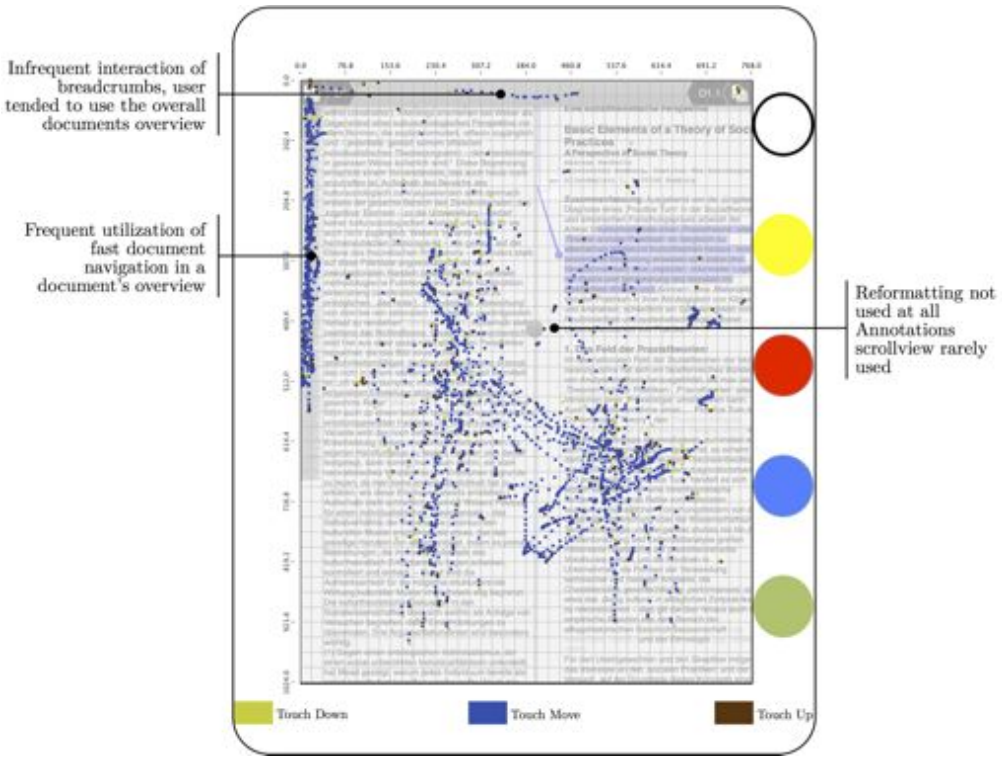
12. Plot of subjective workload for text search tasks



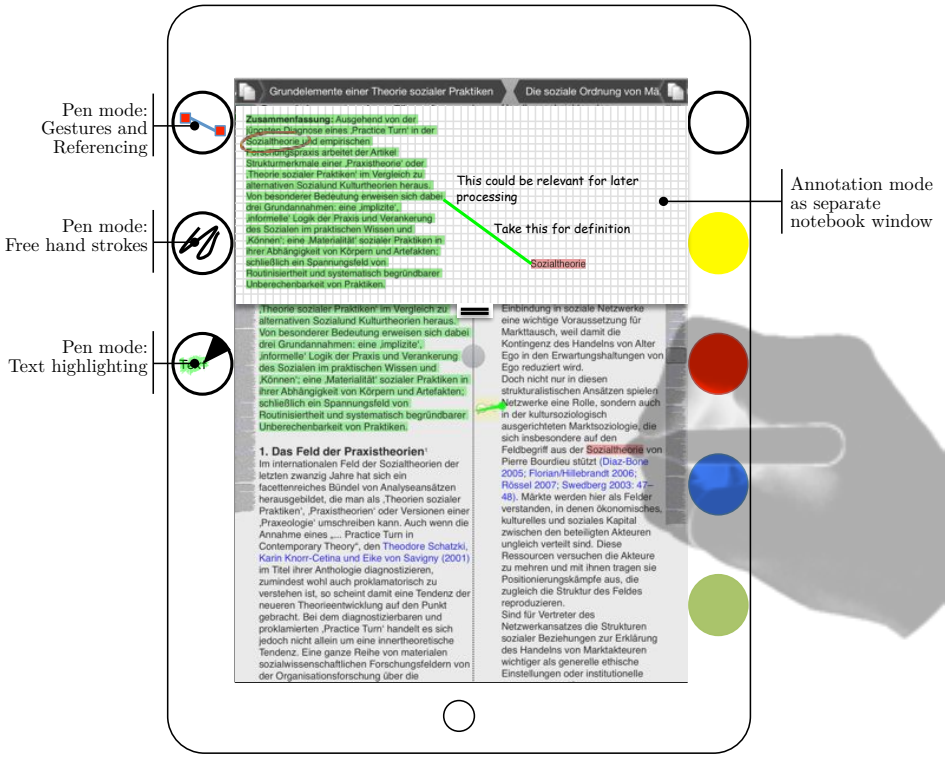
13. Log data: hybrid approach - Pen interaction



14. Log data: hybrid approach - Touch interaction



15. Design proposal for annotating



16. Overview User Study Evaluation

Approach ***P***: conventional *active reading in the mobile context* with paper Approach ***D***: pure digital *active reading in the mobile context* Approach ***H***: hybrid paper like *active reading in the mobile context*

The null hypotheses H_0 are generated in comparison between either of the interaction approaches $\boldsymbol{\xi}$ (P, D or H). It is assumed that the investigated utility value (satisfaction, simplicity or time efficiency) of one input approach ξ_1 equals the investigated utility of the other input approach ξ_2, while there are always just two approaches compared with each other.

Annotating

1. $\boldsymbol{\xi_1}$ requires as much *time* **marking text passages** as $\boldsymbol{\xi_2}$
2. $\boldsymbol{\xi_1}$ requires as much *time* **annotating text passages** as $\boldsymbol{\xi_2}$
3. $\boldsymbol{\xi_1}$ requires as much *time* **referencing text passages** as $\boldsymbol{\xi_2}$
4. $\boldsymbol{\xi_1}$ is equal in *user satisfaction* rating as $\boldsymbol{\xi_2}$ regarding **annotating**

Navigation

5. $\boldsymbol{\xi_1}$ requires as much *time* **retrieving documents** as $\boldsymbol{\xi_2}$
6. $\boldsymbol{\xi_1}$ requires as much *time* **locating chapters** as $\boldsymbol{\xi_2}$
7. $\boldsymbol{\xi_1}$ is equal in *user satisfaction* rating as $\boldsymbol{\xi_2}$ regarding **(cross-document) navigation**

Text search

8. $\boldsymbol{\xi_1}$ requires as much *time* **locating words** as $\boldsymbol{\xi_2}$
9. $\boldsymbol{\xi_1}$ requires as much *time* **retrieving emphasized passages** as $\boldsymbol{\xi_2}$
10. $\boldsymbol{\xi_1}$ requires to scan as much *documents* **retrieving emphasized passages** as $\boldsymbol{\xi_2}$
11. $\boldsymbol{\xi_1}$ is equal in *user satisfaction* rating as $\boldsymbol{\xi_2}$ regarding **(cross-document) text search**