Cognitive Abilities, Interfaces and Tasks: Effects on Prospective Information Handling in Email

by

Jacek Stanisław Gwizdka

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Jacek Stanisław Gwizdka
Department of Mechanical and Industrial Engineering, University of Toronto

Abstract

This dissertation is focused on new email user interfaces that may improve awareness and handling of task-laden messages in the inbox. The practical motivation for this research was to help email users process messages more effectively.

A field study was conducted to examine email practices related to handling messages that refer to pending tasks. Individual differences in message handling style were observed, with one group of users transferring such messages out of their email programs to other applications (e.g., calendars), while the other group kept prospective messages in email and used the inbox as a reminder of future events.

Two novel graphical user interfaces were designed to facilitate monitoring and retrieval of prospective information from email messages. The TaskView interface displayed task-laden messages on a two-dimensional grid (with time on the horizontal axis). The WebTaskMail interface retained the two-dimensional grid, but extended the representation of pending tasks (added distinction between events and to-do's with deadlines), a vertical date reading line, and more space for email message headers.

Two user studies were conducted to test hypothesized benefits of the new visual representations and to examine the effects of different levels of selected cognitive abilities on task-laden message handling performance. Task performance on both of the new visual interfaces was faster than on the more traditional textual interfaces, but only when finding date-related information. Selected cognitive abilities were found to impact different dependent measures. Working memory and flexibility of closure had effects on performance time, while visual memory and working memory had effects on user interactions involving manipulation of the visual field, such as scrolling and sorting.

This research contributes to understanding interactions among cognitive abilities, user interfaces and tasks. These interactions are essential for developing two types of interface: inclusive interfaces that work for users with a wide range of cognitive abilities, and personalized and adaptive interfaces that are fitted to individual characteristics.

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Completing a Ph. D. is like running a marathon. The ups and the downs of its various stages are impossible to endure without support from family, friends and colleagues.

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Chapter 1

Introduction

"Wonder is the foundation of all philosophy, inquiry its progress, ignorance its end."
Michel de Montaigne, Essays

1.1 Motivation

The role of electronic mail has increased rapidly since its inception, particularly in the past several years when email has become the prevalent means of communication in organizations. Email is also increasingly used at home, where services such as Hotmail, America On-Line (AOL) or Yahoo! mail are widely used. In 1998, the volume of emails sent in the U.S. surpassed the volume of hand-delivered mail (Hamilton, 1999).

Email is an integral part of American workers' lives. In 2002, 98% of the working adult American population used email on the job (Fallows, 2002). There are estimates that 7.3 billion emails were sent world-wide per day in 2002 (*The New York Times*, 2002). Other estimates are even higher: the International Data Corporation estimated in 2002 that 31 billion person-to-person emails were sent each day, and this number is expected to grow to 60 billion each day by 2006 (Johnston, 2002). Over 30 years after email's introduction, email maintains its status as the "killer app" on the Internet.

The growing number of email users and messages, together with the relative lack of constraints imposed by email, contribute to new, often innovative, and unforeseen, uses of email. Email has long ceased to be *merely* an asynchronous communication tool—it has become overloaded with other uses (Whittaker & Sidner, 1996). Email is used to handle messages carrying a wide variety of information types: to schedule meetings; to manage projects' to-do lists; to receive and delegate tasks; to receive, disseminate and exchange documents; to find and quit jobs; and, finally, to build and maintain social relationships. Yet email programs were not designed to support the dramatically increasing complexity and range of *novel* activities performed in email. The messaging metaphor, which underlies the design of standard email programs, has not changed since email's inception in the early 1970s.

Handling an increasing number of messages in functionally overloaded email inboxes is cognitively demanding on users. However, this situation also provides rich opportunities for research in the area of understanding user practices, and in exploring novel technological solutions that help users to perform email tasks. This thesis is focused on email messages that require revisiting and repeated processing, and which are typically kept in email folders. This thesis seeks to understand user practices involved in handling these messages, in order to re-design the email user interface (UI), and to evaluate the modified user interface with respect to demands imposed on human cognition.

The increasing complexity involved in processing email inboxes can potentially be influenced either by a collective change in users' information practices or by introducing a technological solution. In this research, I propose applying a technological solution by making a UI intervention that is informed by email practices and relevant theories; this intervention, when implemented, may in turn influence these practices. I examine the effects of the modified email interface on users, concentrating in particular on differences between user groups.

Interaction with email interfaces is an instance of human-computer interaction (HCI). HCI has been analyzed from different perspectives according to numerous theories: human information processing (Lindsay & Norman, 1977; Card et al., 1983), the language-action perspective (Winograd & Flores, 1986; Suchman, 2001), distributed cognition (Hutchins, 1995), situated action (Suchman, 1983; 1987), and activity theory (Kaptelinin, 1997; Kuutti, 1997; Nardi, 1996), to name just a few of the most widely used theories.

Human information processing, although recently criticized on the grounds of limiting the unit of analysis to individual cognition, is by far the most influential psychology-based theory in HCI. Human information processing is based on two fundamental notions: 1) human performance, from the perception of displayed information to a response, is a function of several processing stages; 2) a human can be treated as a complex system that can be decomposed into subsystems, and that can be analyzed in terms of these subsystems and their interrelations. In one of the human information processing-influenced HCI study models (Proctor & Vu, 2003), empirical studies were employed to evaluate the information processing demands imposed on people by interaction tasks. That approach is favoured in this thesis.

People differ in their information processing capacities and styles. This research evaluates information processing demands imposed by email in the context of those individual differences. Since people differ widely in cognitive styles and in how they manage information, one could expect individual differences in both email handling strategies and in interaction styles with email.

Creating a modified user interface aims to achieve better usability (Mayhew, 1999). The notion of usability is generally considered with respect to a broad cross-section of people using a specific artifact (e.g., a software interface) to carry out specific tasks. In this thesis, my research interest is in augmenting this broad notion of usability by examining levels of usability for specific groups of individuals. Thus, usability is described by an additional set of parameters that specify groups of people for whom usability is improved or degraded. One way to characterize population groups is by different levels of cognitive abilities, which in practice is achieved by administering tests of these abilities. Approaching usability in such a way has the objectives of reducing individual differences in performance between users and designing more inclusive interfaces (Egan, 1988; Dillon & Watson, 1996).

The specific methodological approach of this thesis is task-centric evaluation (Neuwirth et.al., 1998), where reference tasks (Whittaker et al., 2000) are developed and used to evaluate alternative email user interfaces. User interface evaluation seeks to show how different cognitive abilities affect performance and also strategies for different combinations of user interface and task (Cribbin & Chen, 2001; Zhang & Salvendy, 2001).

1.2 Thesis Objectives and Research Questions

As stated earlier, this thesis is focused on email messages that require revisiting and repeated processing, and that are typically kept in email folders. Messages need to be revisited and re-processed, because they are associated with actions that are to be performed in the future. Future actions may be described or imposed, explicitly or implicitly, by an email message. Such messages will be referred to as *future messages* or *prospective messages*, while activities that are to be performed in the future, such as attending a meeting, visiting a friend, writing a paper, or replying to an email, will be referred to as *pending tasks*.

The general challenge, at the applied level, is how processing of overloaded email inboxes can be made easier, and, in particular, how handling of messages carrying pending tasks can be made *less cognitively demanding* on email users. Consequently, this research examines new email interfaces that are designed to make processing of pending tasks less cognitively demanding by making these tasks *more visible*. The research is then concerned with evaluating the impact of the designs and users' cognitive abilities on performance.

In the course of this research, a number of themes were addressed, including those introduced above. The research themes are described below and serve to orient the work presented later in the thesis.

The most general research questions being answered in this dissertation are as follows:

1. How is performance on email interfaces and tasks affected by different levels of relevant cognitive abilities?
2. Can a graphical representation benefit email users, and in particular those with low levels of relevant cognitive abilities?

The first question is concerned with how tasks carried out by users in different email interfaces are affected by different levels of users' cognitive abilities. The second question is concerned with the effects of graphical representations of prospective email messages on users with low levels of cognitive abilities. These research questions involve three core elements: *email users*, their *tasks*, and *email user interfaces*. To answer the more general questions, a series of more detailed questions was posed, examining specific aspects of the three core elements, and their interactions.

The first step in answering the main questions was to understand user goals and actions from the perspective of prospective information handling in email. *What strategies do email users employ to handle future messages? Are there differences between user strategies?* Current email practices were examined by using a combination of interviews and observations in-situ (Figure 1.1). The results were used to further focus the research and to inform the user interface design.

The user interface design was focused on supporting retrieval of information from prospective messages. A question was asked: *How can information retrieval from prospective messages be better supported*? Based on the premise that a graphical presentation of pending task information is "better" (because it off-loads cognitive processing) than a textual presentation, modified graphical email interfaces were designed.

Two experimental user studies were undertaken to support, or refute, the claims embodied in the graphical representations. *Is the designed graphical representation of prospective messages (pending tasks) beneficial to users*? *What is the impact of the user interface design on task performance*? Evaluating the (beneficial or adverse) impact of UI design involved assessing user performance on a task carried out by means of UI variants that differed in the amount of graphical elements used. In each study two email interfaces were used, a "visual" interface and a "textual" interface (Figure 1.1).

Returning to the general research questions: *How is performance on email interfaces and tasks affected by different levels of cognitive abilities? Can a graphical representation benefit email users, and in particular those with low levels of cognitive abilities*? Both questions are concerned with understanding the effects of individual differences between people (attributable to cognitive factors) on email tasks. But this leads to the question: *Which cognitive factors are likely to produce differences in performance on email tasks*? Four abilities were selected for this thesis research based on a literature review and the properties of email tasks.

The research considers differences between people (cognitive abilities), and differences between user interfaces (visual vs. text). The thesis uses a task-centric approach. The research focus is on task, which implicitly relates user and system. Such an approach should allow consideration of theoretical and practical issues on both sides of the human computer divide.

Following these considerations, a methodological question arises: *What email task(s) should be used for evaluation*? Both user studies employed *information finding* in the email inbox. This type of task was chosen as realistic and frequently performed by email users.

As noted earlier, user studies were conducted to assess the impact of user interface design on task performance. Following the main research thrust of the thesis, the impact of cognitive abilities was also assessed. *How is performance on email tasks affected by different levels of cognitive abilities*? High levels of cognitive abilities were generally expected to increase the efficiency of information retrieval from the inbox.

Further questions related to individual differences between people arose in the course of this thesis. From the field experiment, it was clear that participants showed distinct prospective email handling styles. Such differences could thus be reasonably expected in the population of the two user studies as well. *Can email users be grouped based on their performance and/or email strategies*? A more interesting issue was to find an explanation of those differences: *Can those differences be related to (and explained by) other differences between population groups studied*?

A research overview described above is shown in Figure 1.1.

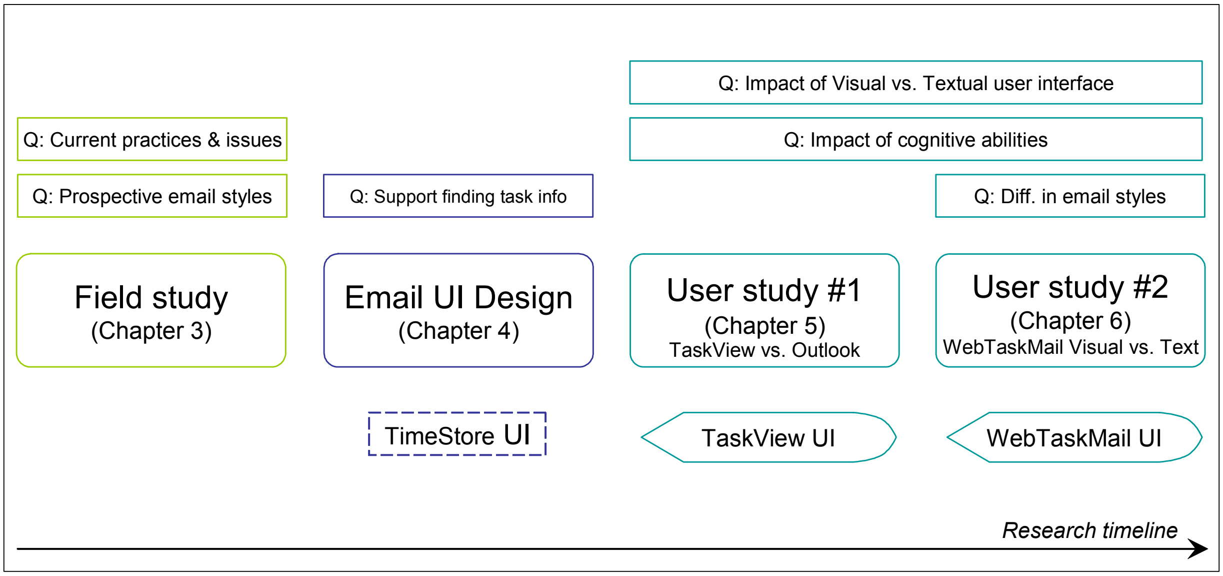


Figure 1.1. Research overview.

1.3 Roadmap of the Dissertation

This research exemplifies one of possible structures of an HCI approach (Eberts, 1994, Chapter 3): background knowledge is gathered; field studies are employed to explore an existing situation and pinpoint problems; these studies, together with a theoretical background, inform the design of new solutions (or re-design), which are then evaluated. Results from such evaluation are used to inform the next design iteration, which in turn may be evaluated.

Chapter 2 (Table 1.1) presents an overview of research related to email use and email interface design. The chapter also provides background on human cognitive abilities and their role in processing email inboxes. Chapter 3 describes a field study that focused on practices of email users, in particular those practices related to managing email messages containing temporal references. Chapter 4 presents the motivation behind the design of two user interfaces that were implemented in the course of this thesis, and it describes them in detail. Chapter 5 describes User Study #1, in which a time-based representation of messages with pending tasks was compared with a more standard user interface. Chapter 6 describes User Study #2, which involved examination of a redesigned user interface. Finally, Chapter 7 ends the thesis with concluding remarks, a summary of contributions made by this research, and a discussion of suggested future research steps.

Thesis Chapter	Research stage
1. Introduction	Research Motivation
2. Background and Literature Review	Background & Related Work
3. Strategies for Handling Prospective Messages	Exploratory Field Study
4. Research User Interface Design	Research User Interface Design
5. TaskView — User Study #1	Evaluation
4. User Interface Design	User Interface Design Iteration
6. WebTaskMail - User Study #2	Evaluation
7. Conclusions, Contributions and Future Work	Summary and Conclusions

Table 1.1. HCI research phases and thesis structure.

Chapter 2

Background and Literature Review

2.1 Introduction

This chapter highlights research related to email use and email interface design. It also provides background on human cognitive abilities and their role in processing email inboxes.

The chapter starts with a review of studies of email use. The studies demonstrate how email use goes beyond asynchronous communication and how email is used to receive, keep, and manage a large variety of information types. Next, the different information types are described from the point of view of their temporal references. Processing email messages imposes cognitive demands on email users. Cognitive abilities are described along with their role in performance on HCI tasks, and in particular, on email tasks. The chapter then turns to a description of email interfaces, discussing how they support described information types and email uses.

2.2 Studies of Email Use

2.2.1 Motivation to Study Use of Email

The first basic email programs (SNDMSG and READMAIL) were written by Ray Tomlinson in 1972, while the first full-fledged email program (MSG) was created in 1975 by John Vittal (Leiner et al. 2000; Jacobsen 2003). Until the end of 1970s, email use was limited to hosts on ARPANET[1]. End of the 1970s and beginning of the 1980s, saw a creation of several non-military networks; those included: USENET (1979), BITNET and CSNET (1981), and EUNet (1982) (Leiner et al., 2000; Zakon, 2003; Jacobsen, 2003). The networks provided many organizations with access to email messaging protocols and applications. From the very beginning email was a “killer app”. Its wide spread use was confirmed by the amount of network traffic taken by the email message transmissions[2]. Yet

1. The number of hosts reached 200 by 1979.
2. In 1973, email traffic accounted for 75% of all network traffic on ARPANET (Leiner et al., 2000).

the great convenience of electronic messaging was soon followed by information overload created by the burgeoning number of email messages (including junk). Realization of the dangers of electronic "junk" mail came very early. Postel (1975) noted that the design of most email systems made it difficult to block junk mail. His foresight would prove to be correct when spam began to fill users' email boxes.

Since the email protocol itself and most email systems could not be easily used to reduce information overload (and email junk), different kinds of solutions were researched and proposed early on (Hiltz & Turoff, 1985; Malone et al., 1987; Flores et al., 1988). However, (as with many other software applications) those early solutions were generally not preceded by studies of email use.

Email is an (essentially) open environment, which is amenable to different uses. Basic characteristics of email as a computer mediated communication system are as follows:

1. *Remote asynchronous communication*. Email messages are exchanged *asynchronously*. Messages sender and receiver decide when to send, read, and reply to an email message. Both parties can be separated by large geographical distances.
2. *Permanent record of communication*. Email *automatically* provides a permanent record of exchanged messages.
3. *No internal structure* (intra-message). Email message, according to today's standards and protocols, has two main parts: a header and a body. Syntax of a message header is well specified, and, at a minimum, contains the following information: who sent the message (From:), to whom message was sent (To:), message title (Subject:), and date. Message header is extensible, and new fields can be added. In contrast, the body of a message has no specified syntax, it can contain any ASCII text[1]. (RFC 822 - Crocker 1982)
4. *Little external organization* (inter-message). Fields that exist in email headers can be used to create several types of message organization: by sender, by subject, and in a temporal sequence. Combination of these fields is employed to create message *threads*. Threading was one of the first ways of organizing messages. Threading has been

1. Additional standards specify other types of content html, xml, embedded objects, attachments, etc., that can be transmitted in an email message (in general specified by the MIME standard: RFC 2045 - Freed & Borenstein, 1996). These other types of message content does not change the point. Although, the content may have an internal structure, email protocol specification does not define this structure.

extensively used by many USENET news readers (large on-line discussion groups created in 1979). (RFC 1036 - Horton & Adams, 1987)

5. *Lack of communication rules*. There are no enforced rules for the exchange of messages. The on-line community had created the so called “Network Etiquette” or *Netiquette*. However, *Netiquette* serves as a guide for good on-line behaviour and is not enforced (RFC 1855 - Hambridge 1995).

The lack of imposed structure and communication rules cause email use to be determined, to a large extent, by the *content* transmitted in email messages. With user composed and generally unstructured message content, email use becomes open to user interpretation and invention. It is thus important to establish empirically how email is *actually* used by people.

2.2.2 Studies of Email Use

Email was first (1970s) used by researchers and academics. Subsequently, it has spread to offices and homes (1970s/1980s). Email was studied in many different contexts and from different perspectives. Researchers examined acceptance of email and its impact on organizations (Sproull & Kiesler, 1991; Orlikowski et al., 1995). Sociologists studied dynamics of email communities (Kot, 1998), how social capital is transformed by email, and application of social influence theory to email (Stuckey, 1998; Connel, 2000). Specific aspects of email use in organizations were studied, how email is used by managers (Bell, 2000), email effectiveness (Eastman, 1999), and the effect of email interruptions on workers (Jackson et al., 2001; Jackson et al., 2003).

Of particular interest to this thesis are studies examining use of email functions from the perspective of information management and processing. Selected studies taking this perspective are discussed below.

In an early field study Mackay (1988) described how email supports a variety of activities that reach beyond the communication functionality. She observed three main functions of email use at work:

1. *Information management*—functions related to gathering information in email, to processing and organizing information in email for later retrieval, and to disseminating information by email.
2. *Time management*—electronic task assignment. Tasks need to be organized and prioritized in email.
3. *Task management*—delegating and receiving tasks electronically. Tasks and their assignment need to be kept track of.

Nearly a decade later, the picture had not changed. Whittaker and Sidner (1996) observed how, in addition to conducting conversations through email, the email inbox is used as a repository of information containing to-do's, to-reads and other messages that generally cannot be dealt with immediately upon reading. Their taxonomy of email use contains: 1) *Asynchronous communication*; 2) *Task management*; and 3) *Personal archiving*. The second category (*Task management*) corresponds to the categories number two and three in the Mackay's taxonomy, while the third (*Personal archiving*) corresponds to the category number one in the Mackay's taxonomy. Whittaker and Sidner describe three types of strategies employed by email users, and divide the users into the following groups:

1. *No-filers*—users who do not make use of folders and keep majority of email messages in one incoming email folder;
2. *Spring-cleaners*—users who made use of folders (and had even extensive folder structures), but who filed their email sporadically, about one to three months;
3. *Frequent-filers*—users who made an attempt to file messages into folders daily.

No-filers and *spring-cleaners* had problems keeping up with task management in email, as well as with filing email. *Frequent-filers* encountered relatively few problems, but, as the authors observed, their relative success comes at the cost of time regularly spent trimming their inboxes. But even this at-the-moment-successful situation may change with increased volume of email, when time required to read and respond to a message, would not allow them to spend enough time on managing information in their inboxes.

Why do users encounter problems in email? Whittaker and Sidner (Whittaker & Sidner, 1996) explained that email programs are designed to facilitate a simple one-touch email handling model, where incoming informational email messages (i.e., not requiring a response), are read, and then either deleted or filed. Incoming messages that form part of a correspondence, (i.e., requiring a response), are answered, and then either deleted or filed. The one-touch model thus implies only three possible states of an email message: 1) unread in inbox, 2) filed in another email folder, or 3) deleted in a trash folder. The message may later be retrieved from an email archive, but it is not *active* any more. The multitude of email message types, combined with the use of email inbox to manage tasks make the one-touch model not applicable anymore to email handling.

More recent studies paint an increasingly complex picture of email use. Email was described as the place where work is received, delegated, and managed. Email was likened to a habitat, indeed an *electronic habitat,* where people spent significant amounts of their working time (Bellotti & Smith, 2000; Ducheneaut & Bellotti; 2001). Email was found to be used to manage files received as attachments, to manage complex work processes, including debates, and collaborative group problem solving (Bellotti et al., 2003).

However, even this already complex picture of the variety of email uses is not yet complete. One of the roles of communication media, email included, is to create, maintain and keep active personal social networks (Whittaker et al., 2004; Whittaker et al., 2002; Farnham, 2002). Email also plays an important role in communication-centric social networks, in particular, in distributed global organizations.

2.2.3 Summary

Email is an asynchronous messaging system that has become "overloaded" with other usages. Email has become an environment for conducting work and maintaining social life. It is used to manage: 1) conversations; 2) information; 3) time and tasks; 4) files; and 5) contacts. This diversity of email use is now widely recognized. Yet most email programs still employ the messaging metaphor that has not been designed to support those activities. Section 2.6 presents email programs created to better support them, while the next section (2.3), introduces information types and describes how they explain issues encountered by email users.

2.3 Information Types and Personal Information Management

The previous section described email uses that go beyond asynchronous communication and showed that email is used to perform a variety of information management functions.

This section first discusses why earlier machine-mediated-communication (MMC) systems have not become personal information management (PIM) systems. The two most popular (and still widely used) MMC systems that preceded email are fax and voice mail. Those systems retained their primary function as messaging systems, though one should also note that fax evolved into a document delivery, distribution and exchange system.

The following discussion assumes a traditional view of fax and voice mail, before media and system convergence started taking place[1]. (An extended comparison of email, fax and voice-mail is provided in Appendix A.)

1. Email messages provide a permanent digital record with (a relatively) easy access to the messages (issues with access to the growing inboxes are described later).
2. Email, fax and voice-mail support access at a message level. However, access to faxes and voice mail is (typically) more difficult than to email messages.
3. A finer grain access level is easier to achieve in email than in fax or voice-mail.
4. Email message content can be processed easier than fax or voice messages.
5. Email messages are easily portable between different systems.
6. Email messages can be accessed at the same time from many places.
7. Email can be used for transmission of a wide spectrum of information types.
8. Direct, personal delivery of email messages makes them more personal and trusted[2].

1. Recently the boundaries between the different message transmission and delivery methods have began to blur, and some of the described characteristics are now shared among email, fax and voice mail.

It is important to remember that, in contrast to fax and voice mail, these characteristics were present in email from the very beginning (1970s), or at least from the moment when email began to be widely used (1980s). Therefore, they served an important role in defining email use. These characteristics might have also contributed to the wide acceptance of email.

Thus email, as used in practice, is becoming a place for personal information management. Analysis of information types that people deal with in their personal computing environments can facilitate better understanding of email use and demands of email tasks. The remainder of this section presents a taxonomy of such information types and discusses demands imposed on the human cognitive system by the amount of information, and by future references contained in email messages.

2.3.1 Personal Information Management and Information Types

Past studies examining how people organize their electronic documents on desktop computers (Barreau & Nardi, 1995; 1997) found three models of information handling, each characterized by different patterns of finding and filing processes. These patterns can be described by three types of information: ephemeral, working, and archived.

1) *Ephemeral information* is characterized as information with a short shelf-life (from hours to a couple of weeks), rarely created by users, almost never filed, and usually kept visible by users on computer desktops. Barreau and Nardi stressed the short-term aspect of ephemeral information as well as the predominant use of visual reminding based on spatial location. Examples of ephemeral information include downloaded news articles, phone numbers, and product information, which are kept for near-immediate "consumption".

2) *Working information* is relevant to the user's current work needs, and tends to be frequently accessed and shared. It is created by the user, or the user's co-workers. Its

2. Of course, one cannot forget at this point, that many corporations keep a record of all email transmissions, and that email messages may be the property of a corporation where one is employed.

shelf life can be measured in weeks or months. Examples of working information include memos, meeting notes, working papers, design documents, and presentations.

3) *Archived information* is only indirectly relevant to the user's current work. The shelf life of archived information is measured in months or years. It is typically highly structured and rather infrequently accessed. Examples of archived information include technical reports, customer files, and archives of all email messages related to a particular project.

In previous work (Gwizdka, 2000) involving a questionnaire-based study of personal information management tools and email, evidence was found for a fourth type of information characterized by distinctive handling patterns and by different temporal reference. This fourth type is called *long-term prospective information* and is defined as follows:

4) *Long-term prospective information* refers to future events or activities. Its shelf-life is typically measured in days to months and is longer than in the case of ephemeral and working information. Long-term prospective information also differs from ephemeral and working information in that it has an explicit temporal structure. It can be created by the user, by the user’s co-workers, or by other external entities. Examples of this information type include scheduled meetings, and calendar entries.

The four types of information are dynamic and characterize states of an information object. For example, a phone number that one needed to call a friend within the past hour changes its state from ephemeral information to archived information, when the phone number is stored in a personal address book.

Table 2.1 summarizes the four information types along with their typical temporal references, requirements for tools that support these types of information and their examples.

Information Type	Temporal Reference	Requirements for Tools	Examples
Long-term prospective	future: days - months	explicit reminding, temporal and event-based organization	scheduled events, calendar entries
Ephemeral	current - short-term: hours - two weeks	opportunistic reminding, disappear after use	phone numbers to call
Working	current - medium term: days - months	organization based on tasks, projects or people, quick access	project documents
Archived	past: days - years	organization based on past events, projects or people	past projects, past emails

Table 2.1. Information types defined by their temporal reference.

In previous work (Gwizdka, 2000), Personal Information Management tools were found to be specialized for information types and used accordingly. The PIM tools were, however, generally lacking integration. Consequently transfer of information across tools was not well supported. However, email was used to receive and transmit all types of information, as well as a working environment for all four types of information. Table 2.2 shows the possible uses of tools as listed by the study participants.

Information Type	PIM Tools					Email
	date-book	to-do list	address-book	loose notes	file folders	
Long-term prospective	✔					✔
Ephemeral		✔		✔		✔
Working					✔	✔
Archived			✔		✔	✔

Table 2.2. Information types in PIM tools and email.

As described by Whittaker and Sidner (1996), the one-touch model of handling email breaks down when messages cannot be acted upon immediately after their first reading. The model fails, because email users deal with ephemeral, working, and long-term prospective information, all of which refer to the future. Messages that carry information of any of these three types are collectively referred to as *prospective* or *future messages*. These messages need to be kept around, and are typically, kept in the inbox. Handling of these messages is not sufficiently supported by the existing email functionality. The issue, in the case of *ephemeral information,* is that opportunistic reminding, commonly occurring during periodic review of the inbox (Whittaker & Sidner, 1996), does not scale up with an increasing number of email messages. In the case of *long-term prospective information*, there are no reminders (other than those set by the user, as, for example, in Outlook) and no temporal or event-based structure to facilitate retrieval and reminding. In the case of *working information*, email folders structured, for example, according to projects, provide only partial support. However, a general lack of reminding functionality, as well as lack of explicit temporal and task-centric structures creates problems also for this types of information.

The one-touch email handling model makes two limiting assumptions:

1. The one-touch handling assumes that an email message can be handled in *isolation* from other messages. The observed email uses (see Section 2.2) provide evidence that this is not the case. Most email messages do not exist in a vacuum; they are part of existing structures and networks. For example, handling a message that is part of an asynchronous conversation may require knowing who else is (or was) part of the conversation, when the previous message exchanges took place[1], and what is the content of previous messages[2]. Having quick access to this information helps (and sometimes is necessary) to process the current message. Recreating the structure and relationships among messages (e.g., structure of a conversation) is cognitively demanding on email users.
2. The one-touch model implies that each email message can only be in one of the three states (described earlier in Section 2.2.2). Thus the one-touch model presupposes that

1. Some email programs (e.g., Microsoft Outlook, Netscape Messenger) support threading, and make this kind of information easily accessible.
2. Part of this information can be included in the message body, as "quoting" of previous messages. But there is no guarantee that email correspondents will not delete it, and if they don't, how much would be left. Furthermore, different email programs include different amount of information when "quoting" a previous email message.

after reading no messages are left for later processing. Contrary to this assumption, email users receive messages related to to-do's, tasks and future events. If these messages are left in email, they need to be referred to at a later time. Information contained in these messages requires access based on temporal references to the future and reminding functionality.

Thus, from the perspective of handling future (prospective) messages, three main issues in email handling are due to:

1. the volume of messages;
2. the need to recreate structure and relationships among email messages;
3. the need to re-visit email messages with future (prospective information) references.

These aspects of email handling impose a high cognitive load on email users. Recreating the "hidden" relationships between messages requires email users to hold simultaneously a substantial amount of information in memory. This imposes load on the user's perceptual channel and on cognitive processing (e.g., working memory, visual memory). Having to remember information that is to be used in the future over a longer period of time imposes a load on prospective memory. The demands on cognitive processing will increase with greater volumes of email messages.

2.3.2 Summary

The above examination of the four information types—ephemeral, working, archived, and long-term perspective—facilitates a clearer understanding of specific types of problems encountered by email users. Three particular challenges were identified: 1) the sheer amount of information (quantity of email messages arriving to email inboxes) 2) those email tasks that require recreating structure and relationships among messages by email users 3) the messages that need to be consulted *again* in the future (quantity of email messages staying in email inboxes or folders after being read). These processes create demand on email user's cognitive facilities. The next section examines the role in human-computer interaction played by specific cognitive abilities. Later sections examine selected solutions addressing the three challenges listed above.

2.4 Cognitive Abilities and Email Handling

Section 2.3 hinted at the important role of cognitive abilities in email processing and motivated further investigation into this area. The amount of information, and the need to (explicitly) recreate structure and relationships between email messages, impose demands on perceptual and cognitive facilities used in on-going (short-term) information processing, such as visual perception, working memory, and visual memory. The need to revisit email messages with future references, imposes demands on cognitive facilities used in long-term information processing, such as prospective memory. This section first defines cognitive abilities, and then discusses their role in human-computer interaction, paying particular attention to how individual differences in cognitive abilities affect performance.

2.4.1 Cognitive Abilities—Definitions

> **Definition 1:** *Cognitive ability*
>
> An ability to perform any of the functions involved in mental activities involved in acquiring and processing information (Coleman A.M. 2001)

2.4.2 Long-term Memory

Memory is one of the most important human cognitive facilities. Different memory elements mediate most human interactions with the external (and internal) world. The basic division is into short-term, or working memory (STM/WM[1]), and long-term memory (LTM). Both have an effect on human interaction with email. This section first focuses on LTM, while working memory, and other cognitive abilities, is described later.

1. The distinction between these terms will be later made explicit.

In LTM, a division is drawn between *semantic* and *episodic* memory (Tulving, 1986; Tulving, 1986; Tulving, 1985). Episodic memory is also referred to as *retrospective* memory. The constructs of *retrospective* and *prospective* memory is now described briefly in terms of their relationship with email functions.

2.4.2.1 Retrospective Memory—Past

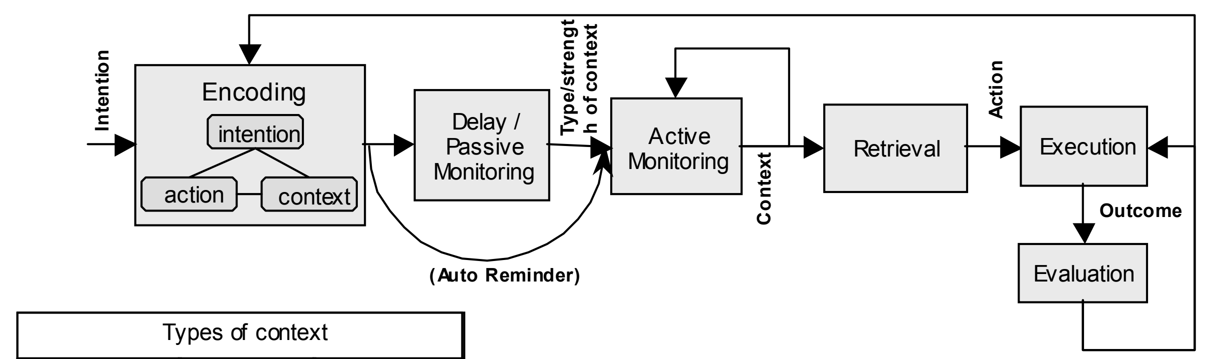
Retrospective memory refers to remembering information from the past. It is memory of events, and, in particular, retrospective memory[1] stores personal experiences (Tulving, 1993; Conway, 1997). The past is the temporal reference of retrospective memory. In this thesis, this kind of memory plays a role mostly in message retrieval from email archives.

2.4.2.2 Prospective Memory—Future

Prospective memory is memory for delayed intentions. It refers to remembering to carry out intentions in the future. Kvavilashvili and Ellis (1996) defined prospective memory in the following way: "Prospective memory is defined either as remembering to do something at a particular moment in the future or as the timely execution of a previously formed intention." Ellis (1996) stressed that prospective memory should *not* be understood as a distinct form of memory, but rather as a set of processes that support formation, retention and retrieval of intended actions, and, therefore, the name prospective memory may be misleading. She suggested that a more appropriate term might be *realizing delayed intentions*. The term *prospective memory* is used as a shortcut denoting this complex set of processes. Based on the elements of prospective remembering (Kvavilashvili & Ellis, 1996; Ellis, 1996; Herrmann et al., 1999), the main processes involved in prospective memory are as follows: 1) Forming an intention to perform action; 2) Encoding the intention to perform action; 3) Delay and monitoring; 4) Retrieval; 5) Action execu-

1. A subsystem of retrospective memory that stores personal experiences is often called *autobiographical memory* (Conway & Bekerian, 1995; Rubin, 1986). The term "subsystem" does *not* mean that this particular memory type exists as a separate entity in the brain. The distinction made here are from a functional perspective.

tion; 6) Evaluation of outcome. Relationships among these processes are depicted in Figure 2.1.



Types of context		
	No cue	External cue
Interruption	Time-based	Event-based
No interruption	---	Activity-based

Figure 2.1. Model of processes involved in prospective memory.
(based on the elements from: Kvavilashvili & Ellis, 1996; Ellis, 1996; Herrmann et al., 1999)

This model is discussed again in Section 3.3.4, Chapter 3, where it will be described from the perspective of supporting prospective memory processes in email.

Monitoring and action retrieval are specific to prospective memory and are not observed in other types of remembering. The future[1] is the temporal reference of prospective memory. Prospective memory plays a role in handling those email messages, which in some way involve delayed intentions, whether these are current messages involving delayed handling, or messages that refer in some way to the future (e.g., actions to-do, future events, meetings).

1. There is also a *retrospective* component in prospective memory. An intention is encoded in the past, with respect to its retrieval time in the future (Burgess and T., 1997).

2.4.3 Working Memory: Attention Control and Storage

> **Definition 2:** *Working memory*
>
> A temporary store for recently activated items of information that are currently occupying consciousness and that can be manipulated and moved in and out of working memory. It consists of a central executive and two buffer stores, called the phonological loop and the visuo-spatial sketchpad (Baddeley, 1986).

Term "WM"[1] will be used to refer to overall working memory capacity, which includes both storage and controlled attention ability. Short-term memory (STM), although sometimes used interchangeably with WM, is less inclusive, and typically refers to storage capacity only (*memory span*).

> **Definition 3:** Memory span
>
> The ability to recall a number of distinct elements for immediate reproduction (Ekstrom, 1976).

According to human information processing models (Lindsay & Norman; 1977, Baddeley, 1986) working memory (WM) plays a critical role as an input buffer for all information incoming from human senses. The limited capacity of WM is a well known bottleneck in human information processing (Miller, 1956). The role of individual differences in capacity of WM in graphical information processing was shown, for example, by Lohse (1997).

There is general agreement on the existence of WM capacity limitations (Miller, 1956), and on a role for WM in mediating between perceptual experience and long term memory. In contrast, there are competing WM models and theories of how WM affects task performance. These include the following approaches:

- the original resource sharing model emphasizing a trade-off between processing and storage (Daneman & Carpenter, 1980);

1. The term "WM" is used throughout this thesis. Although, for practical reasons, WM was measured using the digit span test, which may be construed as a test of STM (since it doesn't assess controlled attention ability explicitly).

- controlled attention view proposing that WM capacity is determined jointly by storage capacity and ability to control attention (Engle et al, 1999);
- task-switching hypothesis according to which WM tasks involve switching between processing and storage - an indirect relationship between the two is postulated (Towse et al., 1998);
- inhibition hypothesis postulating that performance on WM tasks is constrained by one's ability to inhibit irrelevant information (Hasher et al., 1988).

Level of WM is also a main component of some IQ tests of intelligence (e.g., the use of the digit span task in the WAIS-III test (Wechsler, 1997)). WM, and its controlled attention component in particular, may be strongly related to general intelligence (Spearman's *g*) (Conway et al., 1999; Jensen, 1999). Thus working memory is likely to be a major predictor of performance in a wide range of tasks (including email handling) both through the properties that WM may have (Miyake, 2001) and also, through its role as a possible surrogate for general intelligence, and its resulting impact on task learning.

Working memory stands at the nexus of a variety of cognitive processes, including memory and perception, and in many accounts is strongly related to attention. Recent evidence supports this view. For instance, Kane et al. (2001) found (in a visual-orientation task) that people high on working memory could focus their visual attention faster (in the presence of a visual distractor) than people low on WM. Lohse (1997) reported that users who were low on WM needed to refer to chart legends more often (based on eye-tracker recordings) in a budget allocation task, that required reading graphical charts.

2.4.4 Spatial Ability and Visual Memory

Effects of spatial ability on performance has been studied by many researchers, in areas and applications such as navigation in virtual environments and in hypertext, textual information retrieval, and visual information retrieval. For example, Westerman (1995) studied the effects of spatial ability on network navigation tasks. High spatial ability has been found to benefit users particularly in low-semantic contexts, when little semantic structure is applied to the network visualization. An experiment by Vincente, Hayes and Willeges (1987) demonstrated that results from tests of verbal and spatial ability are the best predictors of task performance (searching in a hierarchical file system), accounting for 45% of the variance. The spatial ability predictor was found to be most influential. The effects of spatial ability and associative memory on performance in information retrieval in virtual environments were studied by Westerman and Cribbin (2000). Users with high spatial ability had overall better performance. Similarly, Modjeska and Chignell (2003) found that people with low spatial ability had significantly slower performance when searching for information in a desktop virtual reality environment.

Other studies have demonstrated reduction of the performance gap between different population groups through appropriate design modifications. Sein et al. (1993) conducted a study examining effects of visual ability on the users' ability to learn three software applications. Use of a direct manipulation interface reduced the difference between high and low visual ability users in their study. Zhang and Salvendy (2001) investigated the effects of users' visualization ability and website structure display on Web browsing performance. They found that structure preview reduced the differences in performance between high and low visualization ability users.

Of particular interest to the research on graphical email user interfaces is *visual memory.*

> ***Definition 4:*** *Visual memory*
>
> The ability to remember the configuration, location, and orientation of figural material (Ekstrom, 1976).

Visual memory (VM) is related to iconic memory and to short-term retention ability visual material[1]. Visual memory involves *different* cognitive processes from those employed in other memory factors (Ekstrom, 1976).

1. Some researchers (Petrov, 1970) considered those as separate factors.

2.4.5 Perceptual Closure

> ***Definition 5:*** *Closure grouping law*
>
> One of the four original grouping laws of Gestalt psychology, formulated in 1923 by the German psychologist Max Wertheimer (1880–1943) to explain the organization of parts into wholes by the visual system. According to the law, elements that are perceived to form a *closed* contour tend to be grouped together, so that the array [][][][] tends to be perceived as four rectangular units rather than eight separate elements (Coleman, 2001)

Spatial and visual ability, and working memory, are rarely the only factors affecting human performance in interactive systems. Cribbin and Chen (2001) point out that human performance is typically mediated by multiple perceptual and cognitive factors. They describe factors that play a role in visual information retrieval: visual perception, spatial visualization, spatial relations, closure speed, closure flexibility and perceptual speed; memory (visual memory, associative memory); learning; idea production (associational fluency, ideational fluency).

Processing information in a graphical email user interface requires extracting email message or email message attributes from a distracting background of other messages, which requires an ability to extract parts from the whole. Email tasks that require re-creation of structure or relationships among a group of email messages, or email message attributes, requires an ability to create a whole from pieces. These abilities are referred to as *flexibility of closure* (FC) and *speed of closure* (SC).

> ***Definition 6:*** *Flexibility of closure*
>
> The ability to hold a given visual percept or configuration in mind so as to disembed it from other well defined perceptual material (Ekstrom, 1976).

Carroll (1974) described flexibility of closure as "a process occurring in *short-term memory* whereby a figure is imagined in elation to a surrounding visual-representation field". Flexibility of closure is somewhat similar to perceptual speed. It is also related to, but not identical with, a construct called *field independence/dependence* (Witkin et al., 1971).

> **Definition 7:** *Field dependence-independence*
>
> A cognitive style characterized by the propensity to differentiate perceptual and other experiences from their backgrounds or contexts, a person with a weak propensity of this kind being field dependent and a person with a strong propensity field independent. People who score high on abstract reasoning sub-tests of IQ tests, tend to be more field independent than those who score low on such sub-tests (Coleman, 2001).

According to Hettema (1968) field dependence may lie conceptually somewhere between flexibility of closure and speed of closure.

> ***Definition 8:*** *Speed of closure*
>
> The ability to unite an apparently disparate perceptual field into a single concept (Ekstrom, 1976).

Speed of closure differs from flexibility of closure in that, the subject sees no obvious closure to start with and does not know what to look for, whereas in flexibility of closure the subject knows what to look for, but must disembed it from a more complex figure. Speed of closure is positively identified with the ability to recognize ambiguous visual stimuli (Ekstrom 1976). According to Carroll (1974), speed of closure "requires a search of a *long-term memory* visual-representational memory store for a match for a partially degraded stimulus cue." Wardell (1973) considers speed of closure a possible component of a cognitive style related to extensiveness of visual scanning.

2.4.6 Relationship Among Cognitive Ability Factors

The described cognitive ability factors involve (at least some) separate underlying cognitive processes. However, they are not to be understood as fully independent constructs. For example, flexibility of closure involves working memory processes. The cognitive ability factors provide *indirect* measures of underlying cognitive abilities. Some, like working memory, are better researched and understood, while others, like speed of closure, are understood less well.

2.4.7 Effects of Individual Differences in Cognitive Abilities

A common theme running through my discussions of the selected perceptual and cognitive abilities were the effects of their different levels on human performance. Effects of individual differences on human-machine interaction, and especially of differences in cognitive abilities, have been studied by the human-computer interaction community since the 1980's. Cognitive ability has been recognized as an important predictor of computer-based performance (Egan 1988; Vincente, Hayes & Willeges, 1987; Westerman 1993; Chen & Rada, 1996; Dillon & Weston 1996). The reported differences in performance for computing tasks have been found to be quite large. For example, Egan (1988) reported differences between users in the order of 20:1 for performance of common computing tasks. Egan suggested that these differences could be predicted as well as modified through appropriate design. He proposed a three-step method for designing interfaces that would accommodate individual differences. In the first step, the user characteristics that predict the biggest differences in performance are identified. In the second step, the sources of variation at the task or interface component level are isolated. The third step involves redesigning the task or interface to minimize the offending components so that the benefits of using the interface/system could be maximized for all user groups.

Subsequent research has considered the effect of a variety of individual cognitive differences on performance, including: spatial ability, visualization ability, spatial relations, closure speed, closure flexibility, perceptual speed, locus of control, working memory, associative memory, visual memory, associative memory, associational fluency, ideational fluency, and learning style.

2.4.8 Summary

This section discussed the role of cognitive abilities in human-computer interaction. Section 2.3 discussed demands imposed on perceptual and cognitive systems by the complexity of information processing in email. Understanding user interaction with email systems from the perspective of demands imposed on human cognitive systems is crucial. However, cognitive demands of email tasks have not been much studied before. This is one of the goals of this dissertation.

2.5 Tools Supporting Prospective Information

Before examining email programs designed to provide support for users dealing with one or more email issues, an overview of PIM tools that support prospective information is provided. There is a range of memory processes that can be supported by external devices. Such supported processes can be said to be *externalized*. One of them is *remembering intentions*, that is *prospective remembering* (Herrmann et al., 1990). Supporting prospective memory involves reminding, which can be classified into passive and active. This section will review a small number of representative selection of experimental systems that were created to support prospective memory.

The first class of systems provides solely the reminding functionality. This can be now quite commonly found in commercial desktop and PDA software. For example, Microsoft Outlook's calendar allows one to set reminders on scheduled events; Palm OS DateBook has similar functionality. More sophisticated reminding, based on rule-matching, was part of Khronika (Lövstrand, 1991). Khronika was designed as a system for distributed event-based notification. Information about events was first submitted to an event database. Users could then subscribe to the event database describing their interests and the manner in which they wanted to be notified about those events. The system thus supported reminding about events scheduled at specific times. In addition to automatic notifications, Khronika supported manual browsing (and hence opportunistic reminding).

Figure 2.2. Forget-Me-Not user interface on ParcTab palm device.
(Lamming & Flynn, 1994)

According to the prospective memory model (Figure 2.1), a more accurate reminding requires knowledge about events' context. Forget-Me-Not (Lamming & Flynn, 1994) was designed and built to collect contextual information. The system was based on the use of active badges (Want et al., 1992) and wearable devices (custom built palm top devices[1] such as Xerox Parc's ParcTab, in Figure 2.2). The active badge system provided a means of locating individuals within a building by determining the location of their active badge. Location information was combined with other information from the user's environment (e.g., location-based encounters with others, desktop computer activities, file operations, phone call log) and stored. The recorded data enabled information retrieval based on partial recollection of context (an example query: "what file did I print right after I met Mike in his office?"). It was, thus, retrospective use of the system. However, one could also envision prospective use of the system, whereby the stored contextual information would be used to trigger event and activity based reminders (for example: "remind me to give this report to John, when I meet him next week").

A separate class of system employs time as an organizational metaphor. Lifestreams (Freeman & Gelernter, 1995) introduced a time-ordered stream of documents as a single unifying document organization metaphor (Figure 2.3).

1. The Forget-Me-Not system was built before commercial systems were available on the market.

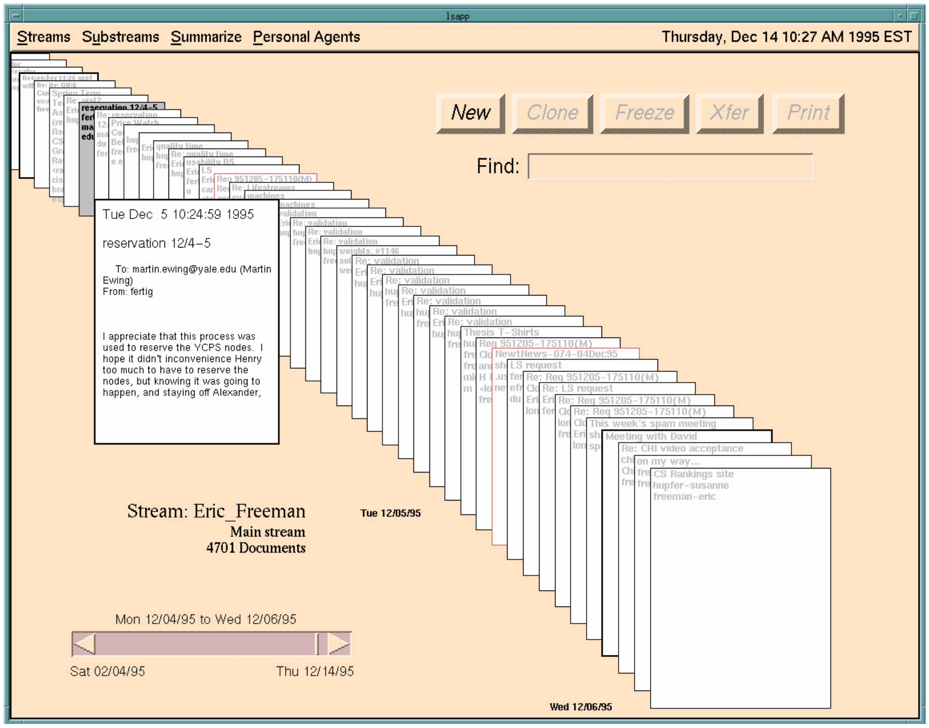


Figure 2.3. Lifestreams user interface.
(Freeman, 1997)

To post reminders and schedule information users could create documents “in the future” (that is with a future time-stamp). An example could be sending email that would arrive in the future. When the time came, the *future* document would *appear* automatically on the desktop. The Lifestreams model, however, did not provide support for *un-timed* future documents (e.g., to-do’s), and, unless the user periodically *dialed-into-the-future*, there was no awareness of what is coming up, until the future time came. Thus, the Lifestreams model might work well in an ideal world, where everything could be precisely scheduled and executed.

The kind of functionality described in this section is typically missing from current email systems. The next section gives an overview of email user interfaces, including systems designed to support selected functions of prospective memory.

2.6 Email User Interfaces

In principle, three approaches to supporting information management in email are possible. In the first, the support is provided directly in email. In the second, email is integrated with other information management tools. In the third, information is transferred from email to other tools to be managed there. This section focuses on the first category and provides an overview of selected email systems that explore solutions at the user interface.

Most email programs employ the messaging metaphor and has not been designed to support email users in performing activities other than simple asynchronous conversations. Described below recent research in the area of email interfaces takes the view that the presentation of messages as a textual list, as used by most current email interfaces on the market, omits important information that is necessary for efficient processing of different types of messages.

2.6.1 Making Messages and Their Relationships Visible

As discussed earlier, processing email messages requires users to extract information from messages and to re-create the structures and relationships between those messages, thereby entailing cognitively expensive tasks. These tasks can be made easier and less expensive for users by making the messages and their relationships *visible* or perceptually explicit, so that part of the processing is moved to the perceptual system, thus offloading the cognitive system (Simon, 1978; Larkin & Simon, 1987). In this context, email systems can be characterized from two perspectives: 1) what message attributes, or what type of message relationships are made visible; and 2) what is the goal of making this information visible, that is, what user tasks are supported.

Two groups of email interfaces presented below employed a variety of visualizations to show relationships among messages in order to support two email tasks: a) handling conversations, and b) managing contacts.

a) Supported task: tracking and accessing conversations in email.

Rohall and colleagues created a series of visualizations of message threads and thread timelines under a common project name "Reinventing Email" (or ReMail) (Rohall et al., 2001; 2002; 2004; Kerr 2003). In particular, Kerr (2003) used temporal order of messages to show sequence and structure of conversations. *Thread arcs* (see Figure 2.4) provide a visualization of the message's reply sequence. The currently selected message, along with arcs to its parent and children, are highlighted with dark colour. Unread messages are indicated with a black border. Messages that the user has sent are hollow. *Thread arcs* maintain compactness with either deep or wide trees, while clearly displaying chronological order (older messages are drawn to the left). (Figure 2.4).

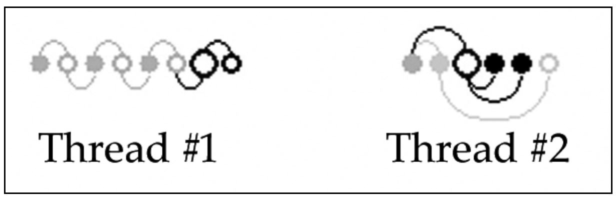


Figure 2.4. Thread Arcs show structure and chronological order of conversations.
(Kerr, 2003 — © 2003 IEEE)

Venolia and Neustaedter (2003) proposed a mixed-model visualization that integrates sequential and tree views of email conversations (the model will be called: MixedConv-Viz). This visualization simultaneously presents temporal sequence and reply relationships among the messages of a conversation and makes both visible at a glance (Figure 2.5). Left-hand side of the interface shows a list of email conversations with reduced detail. Individual conversations are separated with horizontal lines. Each entry in the conversation list contains the name of the conversation originator, the subject of the first message in the conversation, and an indication of each unread message in the conversation.

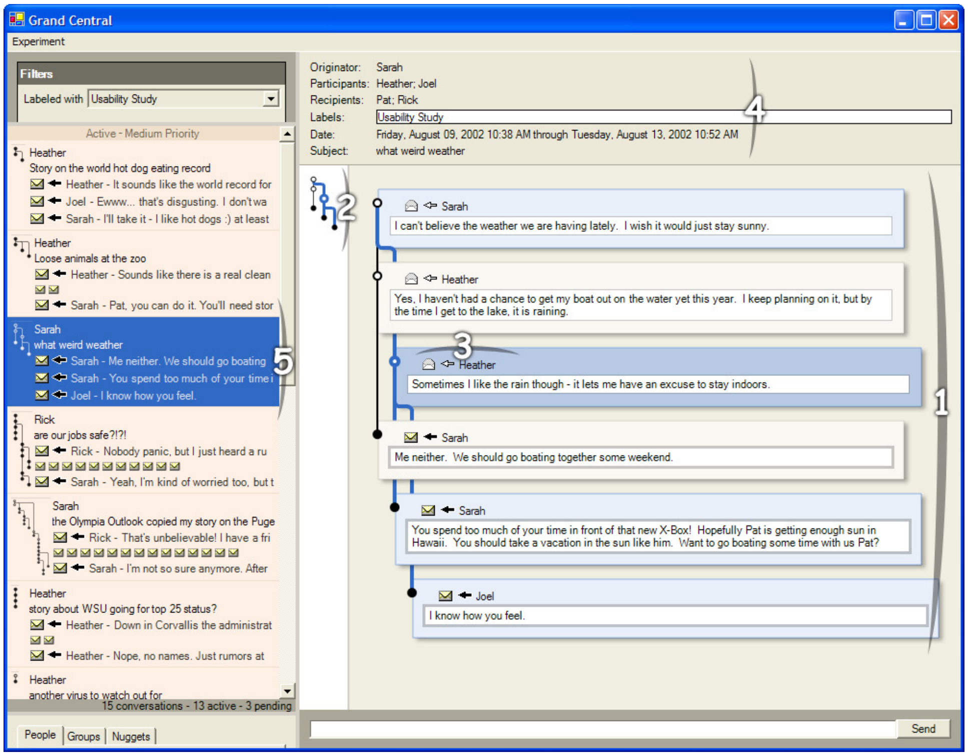


Figure 2.5. Mixed-model visualization of email conversations

(Venolia & Neustaedter, 2003 — © 2003 ACM)

Highlighted in the list (5) is the conversation that is being viewed in the individual conversation panels (2) and (3). Panel (2) shows schematic visualization of the selected conversation, while panel (1) presents the detailed visualization (1). Panel (3) shows information from a selected message (sender name and the beginning of the message body). Panel (4) is devoted to summary information about the conversation. The top three fields show the *originator* of the whole conversation, other contributors to the conversation (*participants*) and those who have received but not sent messages as a part of this conversation (*recipients*). Other fields show the labels that have been applied to the conversation, the date range spanned by the conversation and the subject of the first message. The visualization was positively evaluated by users in a small pilot usability study (Venolia & Neustaedter, 2003).

b) Supported task: creation and maintenance of social networks through email.

ContactMap (Nardi et al., 2002) extract all potential contacts from email messages. Tools are provided to help the user select and organize their contacts on the map (Figure 2.6). Users determine which contacts get added to the map, and how the map is organized. The map can be used to access and initiate email communication with a selected person. ContactMap helps users keep contacts in mind through explicit alerts and implicit reminding. Personal Map (Farnham, 2002) provides a visualization to aid contact management in email. The visualization is created based on the analysis of co-occurrence of people in email messages. The same algorithm was also used in an Outlook add-on, which provides a list of related people when replying to an email message. Most participants of a small user study judged the Personal Map's algorithm as accurately representing their email contacts.

Figure 2.6. ContactMap—Accessing messages exchanged with selected contacts.
(Whittaker et al., 2004)

2.6.2 Use of Time in Email

Time provides an important organizational principle. Chronological order was used in visualizations of message threads discussed above (Figure 2.4 and Figure 2.5). Time, as an attribute of past events, is strongly related to human autobiographical memory (see Section 2.4.2.1 on retrospective memory). Time as an attribute of future events is related to prospective memory (see Section 2.4.2.2). Email messages can refer to time in multiple ways. The possible temporal references contained in messages are as follows:

1. *Message sent time*. When was the message sent? The message sent time is always in the past.
2. *Message arrival time*. When did the message (or its header) arrive to the inbox? The message arrival time is always in the past. Some email programs make a distinction between those times, and allow users to display either one.
3. *Message seen time*. When was the message seen by email user? This time is not necessarily the same as the message arrival time. That difference can have an implication for the design of visual representations, which may not be the same for all users.
4. *Message body reference time(s)*. This type of temporal reference can answer many different questions. For example, when is the next meeting? when is the project's deadline? Temporal references are embedded in the body of a message. Messages can refer to the past, the present, or the future.

These timelines are embedded in email messages. Some of them are embedded explicitly, others implicitly, that is, message sent and arrival are explicit, message reference time can be both explicit or implicit, while message-seen time is implicit[1].

1. Unless this time is recorded by "request-read-receipt feature, but even in those cases the exact time recorded depends on email server / program, in some cases the time is server receive time, in other it could mean received and opened in email program.

A chronological display, according to message *arrival time*, can be found in most current email programs. Figure 2.7 shows an email folder from Qualcomm Eudora, a popular email program (Qualcomm, 2004).

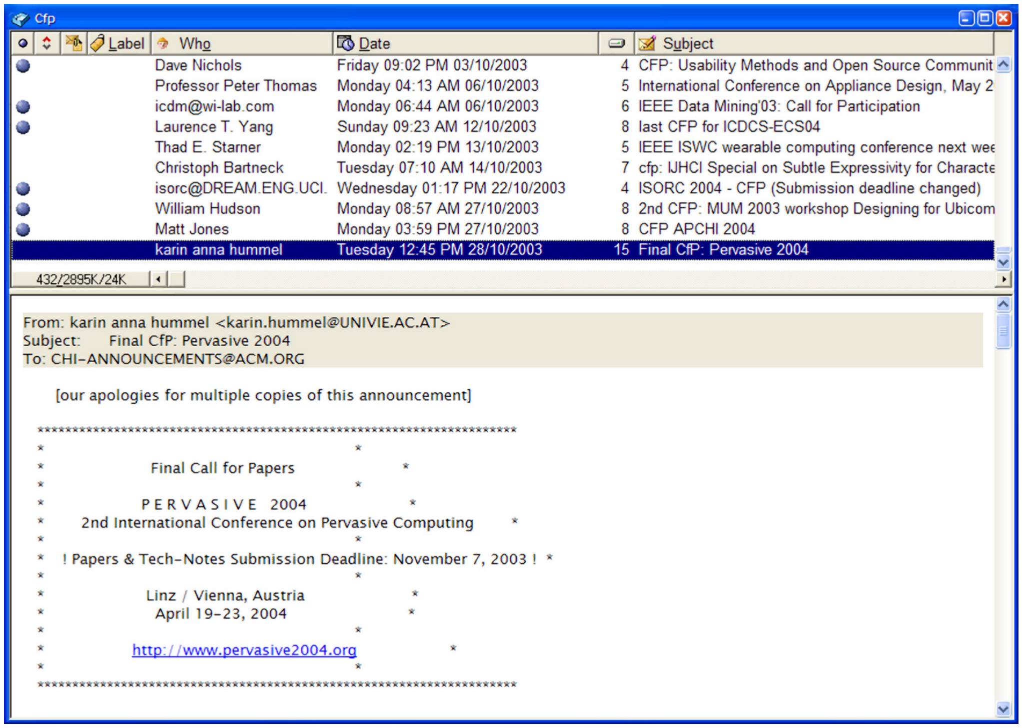


Figure 2.7. Contents of an email folder sorted by message *arrival time* .
(screen-shot of an email folder from Qualcomm Eudora 6)

Message arrival timeline can be used to facilitate retrieval of messages by applying human autobiographical memory to the process of message retrieval. TimeStore (Long, 1994; Yiu, Baecker et al., 1997; Jovicic, 2000) is an example of such an approach. It addressed difficulties that people have in filing email messages and their subsequent retrieval. TimeStore's approach was to free email users from filing by employing a time-based email interface. Messages were automatically organized by their *arrival time* and by sender and displayed on a two-dimensional grid (Figure 2.8). The timeline was used to support message retrieval from an email archive. The two-dimensional representation allowed messages to be located by using cues from autobiographical memory (described in Section 2.4.2.2), when the message was received and by whom it was sent. The authors reported in Jovicic (2000) that users liked the visualization of their email and found it useful for retrieval of both old (inactive) and new (active) messages. The use of message received time to organize email messages in TimeStore was similar to Microsoft Outlook's feature called Journal. However, in the Outlook's Journal, email messages are displayed on a horizontal linear timeline and there is no further organization of messages provided.

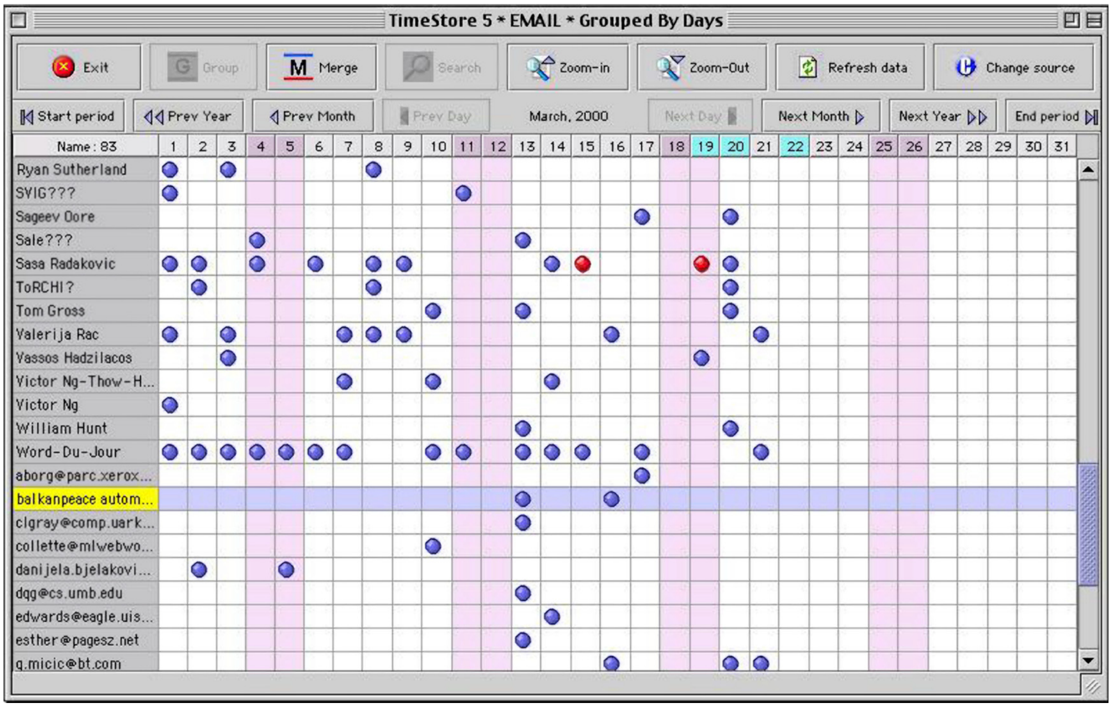


Figure 2.8. TimeStore interface—one month view.

Fisher created two different visualizations of email workspace, a social association map, showing social cliques and relationships (exploiting social relations among one's correspondents, similar to ContactMap and PersonalMap described earlier), and a temporal view of outgoing email activity (Fisher, 2002). In the temporal view (Figure 2.9), messages were drawn as narrow lines, arranged by date (horizontally) and time (vertically). Bursts of email activity are shown as thick blocks; times during which few messages were sent looked like scattered dots. For example, in Figure 2.9 a series of messages exchanged during one week with a particular person is highlighted. This sequence of email exchanges documents interaction with this person. The interaction builds to a very frequent messages exchange just before their regularly scheduled Thursday meeting, after which far fewer messages are sent. Such regular patterns can drive human-to-human interaction on a variety of levels, and can be detected by the human eye with some ease.

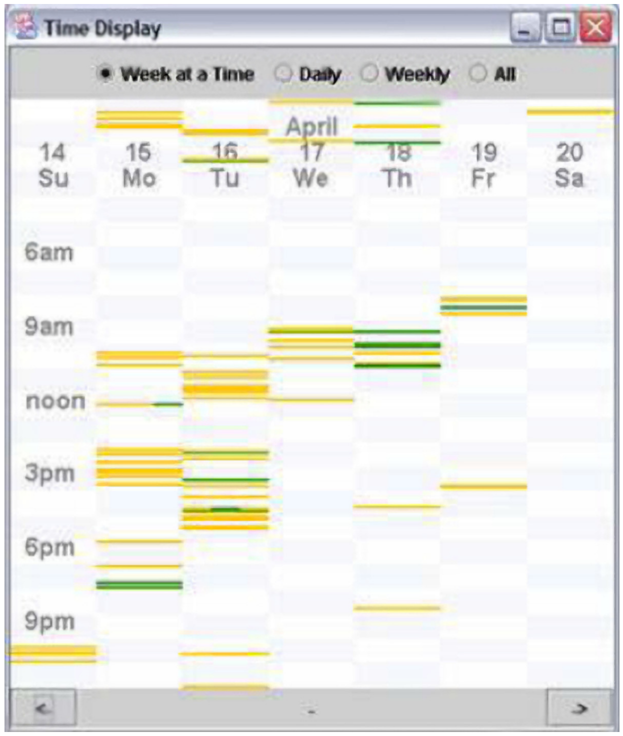


Figure 2.9. Temporal view of email exchange—one week.
(Fisher, 2002)

The following sections describe two specific groups of applications created to support functionality related to prospective information. The first is awareness and reminding, and the second, task management in email.

2.6.3 Awareness and Reminding in Email

Section 2.2 mentioned opportunistic reminding, which is used to maintain awareness of upcoming tasks and events. Maintaining this awareness is part of the monitoring process in prospective memory. Another type of awareness in email is the awareness of incoming messages. The first type of awareness will be called: *prospective awareness* (PA), and the second type: *current awareness* (CA). Both types of awareness can carry different amount of information. At a very minimum, one can have *binary* awareness, which is simply absence or presence of information. In case of CA, notification about new email arrival is an example of a binary awareness. Towards the other end of the spectrum, awareness can contain more information, for example, attributes related to information source, priority, and time. A few systems were designed to specifically support awareness (or monitoring) of email (and possibly also other information sources).

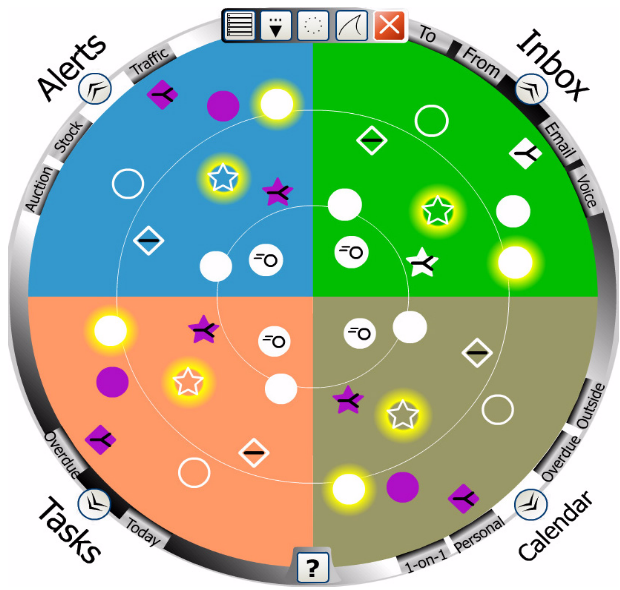


Figure 2.10. Microsoft's Scope—notification summarizer.
(Dantzich et al., 2002 — © 2002 ACM)

Scope (Dantzich et al., 2002) is an example of a CA system (Figure 2.10). The system allowed users to remain aware of notifications from multiple sources of information, including email. The system unified notification from several sources by providing them in one place, a circular radar-like shaped screen. The screen was divided into four quadrants, each corresponding to one information source: email, calendar, tasks, or user-created rule-based alerts. Notification about more urgent items, for example, important email messages were displayed closer to the center. In the evaluation of the initial Scope version users found the system to be "promising" (average subjective rating of 5.3 on a 7-point Likert scale) (Dantzich et al., 2002)

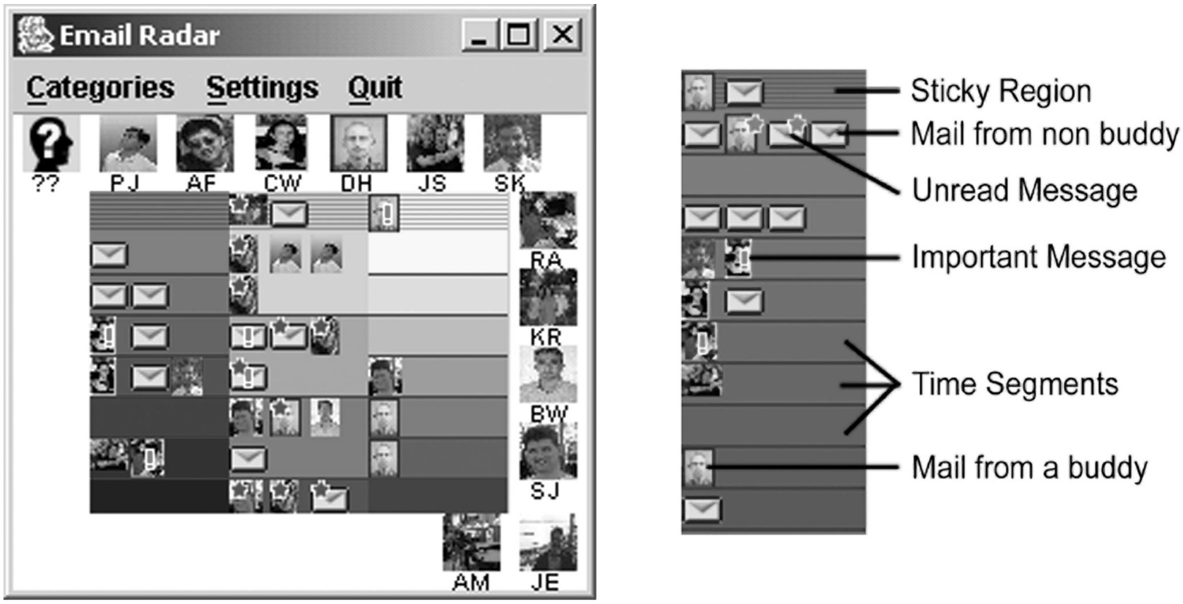


Figure 2.11. Email Radar display (left) and its details (right).
(Miller, 2002)

Email Radar (Miller, 2002) was an example of a CA & PA system (Figure 2.11). It was a peripheral display for email messages that provided information about new messages at-a-glance. Email Radar was designed to support reminding and provide an overview of email messages across folders. The goal of the system was not only to provide awareness of new, incoming messages (CA), but also to remind users about existing messages (PA). Such systems, in general, can reduce the amount of information visible to users, so that the information can be more efficiently processed.

2.6.4 Task Management

The second group of email systems supporting functionality related to prospective information are those that use visualization to facilitate management of tasks in email.

Task management is a critical use of email to manage one's activities. Several email interface prototypes have been recently developed to support task management in email. Bälter and Sidner created Bifrost, an email interface that employed a pile metaphor to support tracking of tasks in email (Bälter & Sidner, 2000). Bellotti et al. (2003) created TaskMaster, which provided probably the most comprehensive support for task management in email to date. Based on the premise that the task, and not the message, is the main element of interest, TaskMaster introduced *thrasks*, which were threaded collections of messages. Thrasks were created semi-automatically; the TaskMaster interface provided ways to track and prioritize different tasks. The main distinction from other work was that *thrasks* correspond not only to message threads, but also to generalized collections of messages related to meaningful user activities.

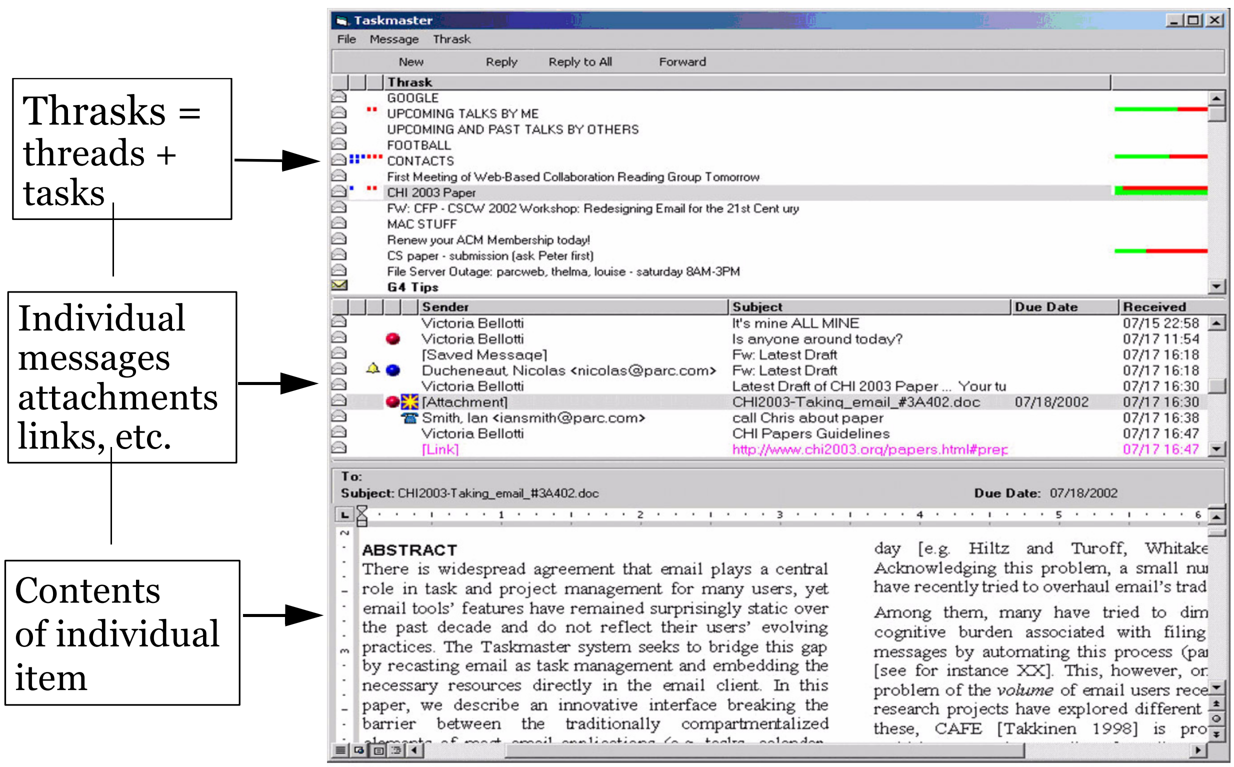


Figure 2.12. TaskMaster user interface.
(Bellotti et al., 2003 — © 2003 ACM)

2.7 Summary

This chapter began with the presentation of email studies that showed how email is used to receive and manage different types of personal information. I described four personal information types, and argued that issues encountered by users in email processing are, at least in part, due to those messages that carry information related to the future (i.e., prospective messages). Individual differences in performance on human-computer interaction tasks were then described with a focus on differences which can be attributed to human cognitive abilities. The chapter finished with an overview of a variety of email interfaces created as a part of research projects (summarized in Table 2.3). While some of them were informed by studies of email use and designed to support well-defined activities performed in email, others were designed to support general message processing functions (e.g., prioritization). Little is known, however, about how to evaluate these new interfaces and visualizations, and how to measure the improvement. Due to this lack of established measures and methodologies, the evaluation of email interfaces with respect to their impact on email handling, if performed at all, is often limited to reports based on subjective experiences. More research is needed that examines what role different email interfaces and tasks might have on user performance.

	Main Supported Functions						
Email System	Message Retrieval	Filing	Reminding	Message organization	Conversations	Contact management	Task management
ContactMap						✔	
PersonalMap						✔	
Email Radar			✔				
Scope			✔				
Thread Arcs (ReMail)					✔		
MixedConvViz					✔		
Bifrost	✔						✔
TaskMaster	✔		✔	✔	✔		✔
TimeStore	✔	✔[a]		✔			

Table 2.3. Summary of functions supported by email systems described.

a. Explicit filing in TimeStore is not needed, and there is no such notion in the system.

The next chapter reports on a field study that focused on the practices of email users. In particular, the study examined how users handle email messages containing temporal references to the future and whether any individual differences in email handling can be established. The two controlled user studies presented in detail in Chapter 5 and Chapter 6, aimed to address the lack of more rigorous evaluation of email interfaces by examining effects of two different email interfaces and email tasks on user performance.

Chapter 3

Strategies for Handling Prospective Messages

(Field Study)

I keep six honest serving-men
(They taught me all I knew);
Their names are ***What*** *and* ***Why*** *and* ***When***
And ***How*** *and* ***Where*** *And* ***Who****.*
Rudyard Kipling*, "The Elephant Child"*

3.1 Introduction

Previous chapter described uses of email and issues related to email handling. This chapter reports on a field study that focused on practices of email users, in particular, those practices related to managing email messages containing different temporal references. The goal of the study was to explore prospective messages, that is messages referring to the future, are handled. These messages will be referred to as *future messages,* or as *prospective messages*. The study focused on temporal message types, processes involved in transferring *prospective messages* between inbox, email folders, and PIM applications outside email and on the use of reminders. This study sought to answer the following questions:

- Are email users keeping prospective messages in email?
- Is handling of prospective messages related to other factors?
- What strategies do email users employ to handle this type of messages?
- Are there individual differences between users and their strategies?
- Can email users be grouped based on their email strategies?

3.1.1 Definitions

For the purpose of studying temporal aspects of email messages, it is useful to define three types of email messages with respect to their time-of-the-next-action:

- *present* or *current messages* – on-going email traffic, messages that have not been read yet. By definition, these messages are always in inbox, and, when automatic email filtering is used, they may also be in email folders;
- *past* or *archived messages* that were already handled and that are kept in email for archival purposes only;
- *future* or *prospective messages* – messages that require performing a task in the future (*other* task then reading this message). Tasks may be *internal* or *external* (see below), and *timed* (to be performed at a specific time) or non-timed (to be performed at any time).

Given, that by definition, *present messages* are always in the inbox, there are four possible combination of the three message types in an inbox: 1) *present* messages only (**p**); 2) *past*

& present messages (**pp**); 3) *past, present & future* (**ppf**); 4) *present & future* (**pf**). These abbreviations are later used in diagrams.

Taking the email-centric perspective, user tasks may be divided into *internal* or *external*. Internal tasks are to be performed *within* email, while external are to be performed *outside* email. Similarly, reminders may be divided into internal, when an email message is a reminder, or external, when an external tool serves as a reminder.

3.2 Methodology

3.2.1 Procedure

The study consisted of two parts: 1) an on-line questionnaire, and 2) one hour in-depth in-situ interviews conducted in the participants' offices. The on-line questionnaire consisted of 43 closed-ended questions. These questions covered the following areas:

- Basic demographics;
- Office desk organization;
- General email background, including information about email programs;
- Handling incoming email messages;
- Handling outgoing email messages;
- Handling time-sensitive email messages;
- Use of folders and filters;
- Use of distribution lists;
- Looking up information in past email in the context of composing messages and in other contexts.

The full questionnaire is included in Appendix C. The in-depth, follow-up interviews probed further into the selected email handling areas. Participants were asked to elaborate on their answers to the questionnaire and to show their email practices in the actual email environment. The more detailed answers obtained in the interview sessions were coded and used in the analyses together with the questionnaire results. The observed user practices were used to create a list of inbox handling strategies (Table 3.5).

3.2.2 Participants

The questionnaire was filled out by 22 participants, 19 of which participated in the follow-up interviews[1]. The study was conducted at Xerox PARC[2]. Study participants were recruited from Xerox PARC and other Xerox laboratories located at the same location. The basic characteristics of the study participant population were as follows:

- 22 participants[3] working permanently or temporarily in a corporate research lab;
- Organizational role of participants: researcher (11 out of 22), research intern (6/22), business intern, administrator, systems administrator, manager, corporate officer (1 of each);
- Area: computer science (15/22), other science (3/22), management & administrative (3/22), business (1/22);
- Work experience - full-time work: from 0 to 37 years (median 5 years);
- Email experience - from 4 to 31 years (median 10 years);
- Number of emails received (self-reported):
  - 8 participants received 10-25 messages per day,
  - 5 participants received 25-50 messages per day,
  - 7 participants received 50-100 messages per day,
  - 2 participants received > 100 messages per day.
- Number of emails sent (self-reported):
  - 2 participants sent 1-5 messages per day,
  - 8 participants sent 5-10 messages per day,
  - 8 participants sent 10-20 messages per day,
  - 3 participants sent 20-40 messages per day,
  - 1 participant sent > 40 messages per day.

1. Three participants dropped out from the study after the first part due to a vacation period.
2. I conducted the study during my research internship at Xerox PARC lab in the summer of 2000.
3. This is the total number of original study participants who filled out the questionnaires

3.3 Results and Analyses

This exploratory study sought to gain insight into user email practices, in particular, those related to handling prospective messages, and to answer the following questions. Is handling of prospective messages related to other factors? What strategies do email users employ to handle this type of messages? Are there individual differences between users and their strategies? Can email users be grouped based on their strategies? To achieve these goals, data collected from the questionnaires and interviews was analyzed to uncover relationships between user variables.

3.3.1 Prospective Information Handling—The Two Styles

The questionnaire and interview results were first analyzed using principal component factor analysis[1] with varimax rotation. The analysis considered all variables from the questionnaire and interviews. A total of eight factors were extracted that accounted for approximately two thirds of the variance. The eight factors thus extracted (Prospective operations, Auto filtering, Reading mailing lists, Source of email overload, Reading email, Experience, Auto-reminders, and Email traffic & reminders) are listed and described in Table C.19 in Appendix C, along with the variables that loaded highly on each of them.

For each factor, its reliability[2] was checked using Cronbach's alpha. Only one factor related to handling prospective information, namely factor #1 *Prospective actions*, had Cronbach's alpha > .7. Other factors related to handling prospective information had alpha < .7, and therefore they are not included in further discussion. Shown in Table 3.1 is factor #1 *Prospective actions* with alpha = .83. The last item in Table 3.1, RDRELEN ("Reading distribution list messages as relevant"), had the lowest loading on the factor *Prospective actions* (FL=.465). After removing this item, Cronbach's alpha increased to .85.

1. As implemented in statistical software package SPSS.
2. Reliability is a measure of a scale's of factor's internal consistency.

Thus, I inferred, that RDRELEN was not measuring the same construct as the other items in this factor and therefore it was removed from the *Prospective actions*.

Factor	Variables	FL
Prospective actions: Interpretation: Time-sensitive info is kept or transferred from email. If kept than email reminds about future events and contains both future info as well as past info. And user tend to look up info in email when not replying.	TRKEEPN: Prospective info kept	.847
	TINFKEEP: Prospective info kept (interview)	.821
	EMINDFUT: Email reminds about future events (interview)	.813
	TINFTRAN: Prospective info transferred (interview)	-.777
	TRSCHEN: Transfer prospective messages to a scheduler	-.670
	TRAGRALN: Transfer prospective messages (grouped)	-.622
	INBFUTNB: Inbox contains msgs. referring to future (interview)	.617
	TINFDELE: Prospective info deleted (interview)	-.561
	INARCHN: Inbox: clean=no past, dirty=contains past (interview)	.556
	LOKNREPN: Looking up info in email not when replying	.536
	RDRELEN: Reading distribution list messages as relevant	.469

Table 3.1. Factor *Prospective actions* from factor analysis[a].

a. Full results are included in Table C.19 and Table C.20 in Appendix C.

After removing RDRELEN, second level factor analysis was performed to uncover underlying dimensionality[1] of *Prospective actions.* Table 3.2 shows a three component solution that was found. Reliability was checked by calculating Cronbach's alpha: for factor #1 alpha=.8; for factor #2 alpha=.73, and for factor #3 alpha=.72.

Aspect of prospective message handling	Variables	Component		
		1	2	3
#1 Transfer or keep	TRAGRALN: Transfer prospective messages (grouped)	**.918**	-.036	-.238
	TRSCHEN: Transfer prospective messages to a scheduler	**.798**	-.158	-.185
	TINFTRAN: Prospective info transferred (interview)	**.677**	-.548	-.058
	INBFUTNB: Inbox contents referring to future events (binary)	**-.673**	.177	.232
	TINFKEEP: Prospective info kept (interview)	**-.543**	.532	.507
#2 Look-up to remind	LOKNREPN: Looking up info in email not when replying	.020	**.944**	.027
	EMINDFUT: Email reminds about future events (interview)	-.336	**.785**	.254
	TRKEEPN: Prospective info kept	-.587	**.621**	.173
#3 Delete or keep all	INARCHN: Inbox: clean=no past, dirty=past (interview)	-.133	.041	**.874**
	TINFDELE: Prospective info deleted (interview)	.303	-.202	**-.802**

Table 3.2. Second level factor analysis[a] for *Prospective actions* factor. (Rotated Component Matrix)

a. Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. Rotation converged in 5 iterations.

1. Cronbach's alpha measures factor's internal consistency, but it does not measure unidimensionality.

Factor *Prospective actions* suggests the basic dichotomy between strategies used to handle prospective messages. Email is either used to manage prospective information or it is not. The three underlying dimensions of prospective actions represent three kinds of actions involved in handling this type of information. *Transfer or keep*: Prospective messages are transferred from email or kept there. *Look-up to remind*: Keeping prospective messages in email is associated with purposeful looking up information in email messages and with using email as a reminder about future events. *Delete or keep all*: If prospective messages are deleted, past messages are deleted too. The last point might suggest that the behaviour related to future message handling does not express differences in processing of prospective information, but that it could be attributed to two more general styles of inbox processing: *immediate handling on reading* vs. *accumulating information* in inbox. The former style may represent an application-specific attitude, wherein various PIM programs are used to manage specific kinds of information (e.g., a datebook is used to manage prospective information) and, since information is transferred out of an email program, inbox is *not* used for information management. The latter style may represent an email-centric attitude, wherein email is used as a site for universal information management. These styles represent a different classification of email user types from those found by Whittaker et al. (1996) (described in Section 2.2.2 in Chapter 2). Their classification was based on filing behaviour, whereas my classification is based on handling of prospective information (without regard to if and how filing is used for that purpose).

Prospective actions factor items were further used to create grouping of participants. K-means cluster analysis was carried out with the ten items constituting the *Prospective actions* factor. Prior to the analysis, each of the items was converted to a standardized normal equivalent (z-scores) in order to remove any affect of scale differences prior to the clustering. A two cluster solution was chosen grouping 8 subjects into the first cluster and 11 into the second cluster.

Item zscores	F(1,17)	Sig.
ZTRSCHEN: Transfer prospective messages to a scheduler	11.128	**0.004**
ZTRAGRAL: Transfer prospective messages (grouped)	24.521	**0.000**
ZTRKEEPN: Prospective info kept	13.969	**0.002**
ZLOKNREP: Looking up info in email not when replying	1.548	0.230
ZINARCHN: Inbox: clean=no past, dirty=inbox contains past (interview)	8.105	**0.011**
ZINBFUTN: Inbox contains msgs. referring to future (interview)	16.404	**0.001**
ZTINFTRA: Prospective info transferred (interview)	12.526	**0.003**
ZTINFKEE: Prospective info kept (interview)	68.895	**0.000**
ZTINFDEL: Prospective info deleted (interview)	27.133	**0.000**
ZEMINDFU: Email reminds about future events (interview)	14.198	**0.002**

Table 3.3. Cluster analysis - ANOVA test for significant differences between clusters.

Analysis of variance was used to interpret the clustering results. There were significant differences between the clusters in terms of behaviour related to transferring, keeping prospective information in email, and in terms of the inbox contents as shown in Table 3.3 (full ANOVA is included in Table C.22 in Appendix C). The one variable that did not differ significantly between the clusters involved looking up information in email messages, not when replying to emails (LOKNREP).

Table 3.4 shows the cluster centres, indicated as z-scores (e.g., a score of 0.69 indicates that the value of the corresponding variable in the cluster centre is 0.69 standard deviation units above the mean for that variable). As can be seen from inspection of Table 3.4, people in cluster 1 generally did not keep prospective messages in email and transferred them to other places. Their inbox did not contain past messages, neither did it contain future message. Accordingly, email was not used to remind about future events. For people in cluster 2 all these relationships were reversed. Cluster 1 people may be therefore called “one-touch email users”, while cluster 2 people may be called “accumulate email users”. The two clusters correspond to the dichotomy and to the two email styles described earlier. Finding the two clusters of subjects, does not mean that subjects employed exactly the opposite types of strategies. Their strategies are more likely to lie somewhere in between. They are described later in Section 3.3.4.

Final Cluster Centers (Item zscores)	**Cluster 1**	**Cluster 2**
ZTRSCHEN: Transfer prospective messages to a scheduler	0.669	-0.629
ZTRAGRAL: Transfer prospective messages (grouped)	0.902	-0.715
ZTRKEEPN: Prospective info kept	-0.828	0.590
ZLOKNREP: Looking up info in email not when replying	-0.373	0.213
ZINARCHN: Inbox: clean=no past, dirty=inbox contains past (interview)	-0.696	0.434
ZINBFUTN: Inbox contains msgs. referring to future (interview)	-0.844	0.563
ZTINFTRA: Prospective info transferred (interview)	0.743	-0.541
ZTINFKEE: Prospective info kept (interview)	-1.022	0.743
ZTINFDEL: Prospective info deleted (interview)	0.895	-0.651
ZEMINDFU: Email reminds about future events (interview)	-0.770	0.560

Table 3.4. Cluster analysis - Item distance from cluster centers. (for item z-scores)

3.3.2 Relationships Among Variables

To further describe relationships between variables as indicated by the factor analysis, and to explore further associations between variables, a number of non parametric association tests (see the Glossary for the description of non parametric statistical methods) were also run. Since most variables were measured on ordinal scales, Sommer's **d** statistic (Siegel et al., 1988) was calculated for those variables[1]. This section reports relationships between variables that describe handling of prospective messages in email.

1. All Sommer's **d** statistics were also calculated for the data file split by the values of the cluster variable. The results were generally similar and confirmed the above relations. However, significant relations were not always present for both clusters, for two reasons: 1) there was not enough data, or 2) all values for one of the clusters were the same.

3.3.2.1 Individual Differences and Prospective Information

There was a significant negative relationship between transferring prospective information from email and the neatness of participants' office desks. Users who transfer prospective information tend to have neat office desks (Sommer's d=-0.485, p<0.005; see Table C.24 in Appendix C). There were significant relationships between cleaning inbox (deleting messages) and keeping prospective information in email. When prospective information is kept, the inbox is also likely to contain past info (Sommer's d=0.453, p<0.05; see Table C.25 in Appendix C), and when prospective information is deleted, the inbox is likely to contain no past (Sommer's d=-0.568, p<0.005; see Table C.26 in Appendix C). Thus, users who delete prospective information also delete past messages from their inboxes. Based on the above three relationships, we may infer that handling of prospective information is related to a person's organization habits. This relationship corresponds to the second-level factor *Delete or keep all*.

3.3.2.2 Monitoring Prospective Information in Email

There was a significant relationship between the frequency of looking up information in email and keeping prospective information in email. When prospective information is kept in email, then information look up in email in contexts *other* than replying or composing a new email message is more frequent (Sommer's d=0.532, p<0.001; see Table C.23 in Appendix C). A possible interpretation might be as follows, when prospective information is kept in email, users consult email messages more often not just to reply to them, but to monitor prospective information contained in them. This relationship corresponds to the second-level factor *Lookup to remind*.

There was a significant negative relationship between keeping prospective information and reading email at specific times (Sommer's d=-0.452, p<0.01; see Table C.27 in Appendix C) and between presence of future events in inbox and reading email at specific times (Sommer's d d=-0.454, p<0.005; see Table C.28 in Appendix C). Thus, users who keep prospective information in email tend not to read email at specific times, but all the time.

A plausible interpretation might be as follows, prospective information cannot be monitored in email at specific times, because there is no *time awareness* in email. Thus users need to employ other effective monitoring strategies (e.g., periodically refer to messages containing prospective information). Those strategies also affect email reading.

3.3.2.3 Use of Reminders

There were significant relationships between use of email as a reminder and the delivery mode of messages from distribution lists (also called mailing lists). Users who used email as a reminder for future actions tended to receive distribution lists as individual messages (Sommer's d=0.396, p=0.04; see Table C.29 in Appendix C) and tended to read distribution lists as regular messages (Sommer's d=0.431, p=0.012; see Table C.30 in Appendix C). A possible interpretation might be as follows, if we assume that prospective use of email requires frequent monitoring of messages, users might monitor prospective information in emails at the same time as they are handling messages from distribution lists.

3.3.3 Flow of Messages

Further analyses were performed to gain insights into user practices and to answer the following questions: What is the flow of prospective messages? How many users keep prospective messages? How many of them use email as a reminder?

Based on participants' responses and their description of strategies used in handling email, it was found that, across all study participants, inboxes contained all four possible combinations of the *past* and *future* messages (Figure 3.1). *Future* messages were kept in inboxes by 15 (N=19) participants. In a smaller number of cases (6/19 participants), present and future messages were also found in email folders, and not just in the inbox (not illustrated in the figure). *Past* messages were found to be kept in inboxes by 11/19 participants. Only 2/19 participants had a "clean" inbox, that is an inbox containing solely *present* messages.

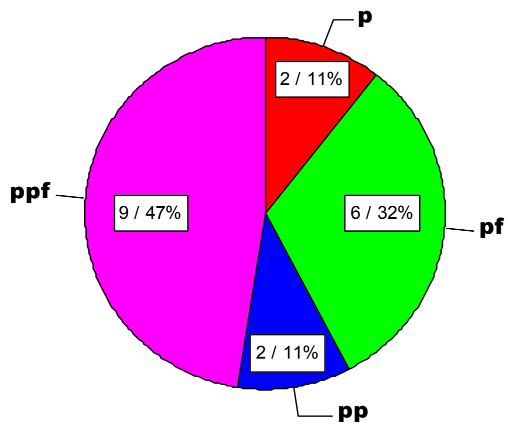


Figure 3.1. Temporal message types in inbox[1].
Reported as a number of participants out of 19 total and as a percentage. Abbreviations used: p = present; pp = present+past; ppf = present+past+future; pf = present+future. See Section 3.1.1

Figure 3.2 depicts flow of prospective messages from the moment when a message is received to its deletion. The figure depicts a flow aggregated over all study participants. As illustrated in this figure, users were found to employ several different ways of handling future messages. At the first decision point <msg read>, which corresponds to stage 2 in the prospective memory model (see Section 2.4.2.2 in Chapter 2), one of the three possible choices was made: 1) message was transferred from email into a PIM tool and deleted from email <Transfer-Delete>; 2) transferred from email, but also kept in there <Transfer-Keep>; or 3) kept in email without transferring it elsewhere <Keep>. The second decision point <msg after action> corresponds to stage 5 in the prospective memory model. This decision was made after an action associated with the message was executed. The message was either still kept in email <Keep>, or deleted <Delete>. It was found that participants who initially kept the messages, were also more likely to con-

1. The data from this study (shown in Figure 3.1) provides information on what percentage of participants kept prospective messages in the inbox. No data was available on what percentage of messages was prospective. However, such data was collected for messages arriving to my own inbox. There were 18% of prospective messages over a period of three months (May-July 2003), and 12.5% of prospective messages over a period of 12 months (May 2003-May 2004) (this decrease was mainly due to the increase of junk mail messages—from below 30% to over 35%). Given, that during this period of time I was primarily involved in the dissertation research, the obtained ratio of prospective messages should be a conservative estimate on the number of prospective messages received by a person involved in several projects (and thus in handling many project deadlines and in scheduling many meetings).

tinue keeping it. Only one participant reported deleting future messages after the action was executed.

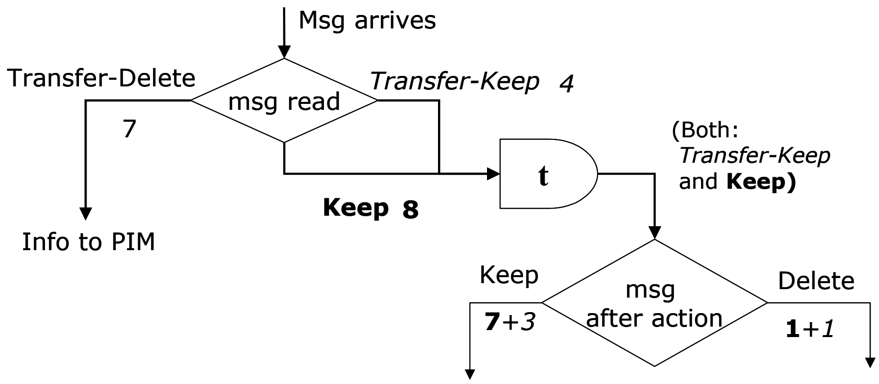


Figure 3.2. Handling prospective information in email.
Numbers are counts of participants following respective strategy. Bold numbers refer to one branch

This division between subjects who transfer and keep future messages in email was suggested earlier by the factor *Prospective operations* and by the two participant clusters.

Given the relatively high number of participants who kept future messages in inboxes, it should be expected to find that email is used in a reminding function. In fact, 17 out of 19 participants used email as a reminder about some kind of prospective actions (internal or external). Moreover, 15 participants used email as a reminder about *external* actions.

3.3.4 Email Handling Strategies and Prospective Memory

In summary, email messages were found to carry information related to prospective tasks. The email environment was found to be used to store, access, and manage this information. Evidence from this study demonstrates the possible extent of this phenomenon. Users who manage prospective information in email need to keep prospective messages in the *processing loop* until a task embedded in an email message is executed. Thus, prospective email messages break down the one-touch email handling model, which supports past and present, but not the future.

Inbox Strategy	Strategy Description	
Immediate processing	Message is replied to, filed, or deleted on the first reading – inbox stays current (represents an *ideal* case - *immediate-filers*)	
Limiting	Limiting inbox processing to about a screen-full of messages	
	Limiting by ignoring	messages beyond one screen are ignored
	Limiting by pruning	delete & file, process one screen
	Limiting by refreshing top	important messages are kept on top of the inbox "stack" (re-emailed to oneself)
Encoding additional information	Adding attributes to messages	flags are added to prospective messages
	Adding structure to messages	prospective messages are filed in special folders
Accumulation	Messages are kept in inbox until handled (represents *no-filers*)	

Table 3.5. Inbox handling strategies.

Dealing with prospective information in email forces users to periodically refer to the messages which are *kept in the processing loop.* Users were observed to cope with this requirement by employing a variety of strategies, which are summarized in Table 3.5. At one end of the continuum of strategies is *immediate message processing*, where messages are replied to, filed, or deleted on their first reading. This is an ideal case corresponding to the *one-touch* email processing model. At the opposite end of the continuum, messages are *accumulated* in the inbox until they are not needed any more. Managing such an inbox may be expensive in terms of cognitive effort and time. Study participants represented various intermediate points on the continuum of strategies[1]. Several participants consciously *limited* the message review process to one screen full of emails. This approach depended on the user's organizational role (e.g., one manager knew that if she missed an important email, the other party would remind her again), and the volume of email traffic. One participant employed the limiting strategy[2] along with re-emailing himself messages requiring future action which were starting to disappear from the screen. Other

1. Different strategies may be combined by one user.
2. Email users' desire to keep certain messages within those that fit on one screen was observed in other email studies as well (Ducheneaut et.al., 2001). In that study, creating nested email folder structure helped users to keep visible more folders and messages on screen.

participants dealt with prospective information by *encoding* further information by adding it to those messages. Several participants in this group added flags to selected messages, while one participant filed prospective messages into specially named folders (e.g., "this week", "next month").

These results suggest that users perform numerous actions to compensate for insufficient support in handling messages containing prospective information. Figure 3.3 shows the model of prospective memory (first presented in Section 2.4.2.2 in Chapter 2) annotated with the existing and missing support for prospective information in email. Spots where the support missing are indicated by the boxes with dashed borders.

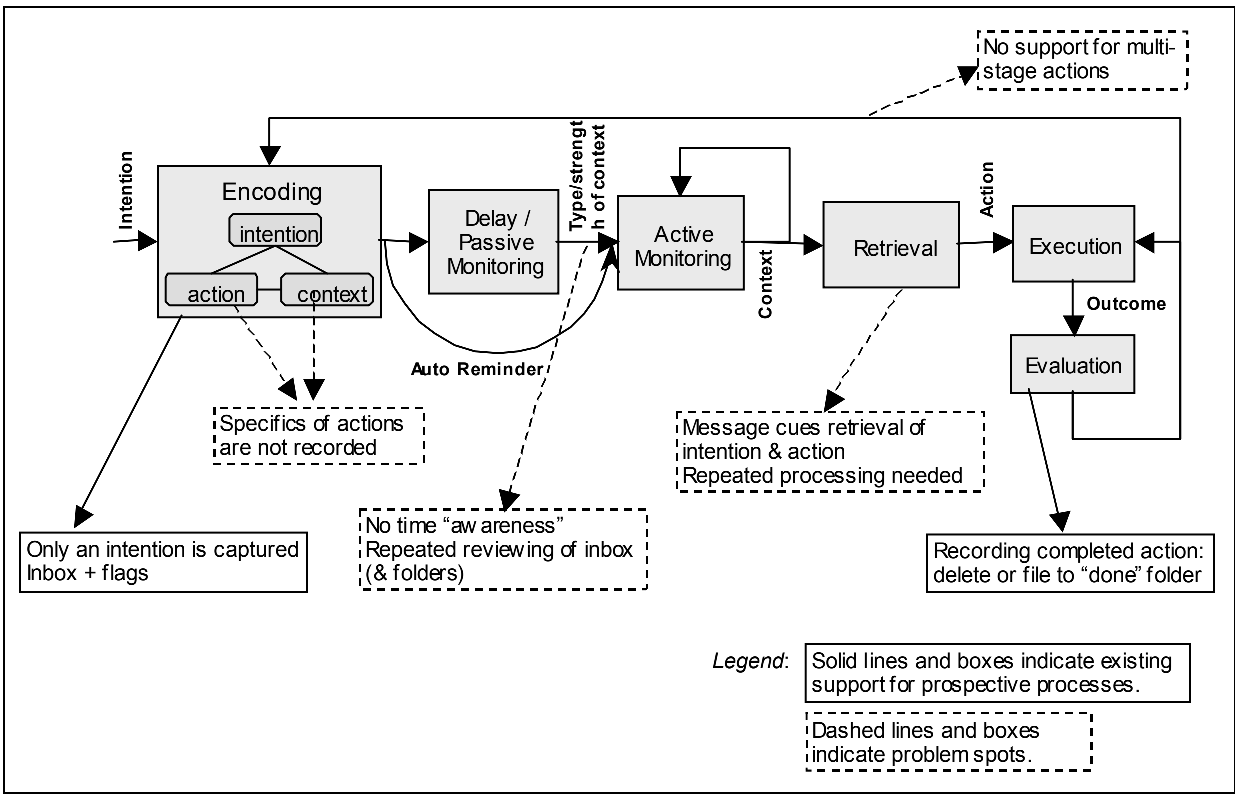


Figure 3.3. Support for prospective memory processes in email.

The following list describes how users in this study dealt with the three issues, shown in Figure 3.3.

1. **Encoding**. Prospective action details and their context need to be remembered by users (or retrieved by re-reading an email message). Currently, email users cope with it by employing the *Encoding additional information* strategies and by repeated reading of messages.
2. **Monitoring.** *Monitoring* of prospective actions needs to be initiated by email users. Existing reminding mechanisms tend not to be used by people[1]. Currently, email users cope with it by employing the *Limiting* strategies, which enable them a) to control the number of monitored items, and b) to keep the important items visible, thus making them available as visual (opportunistic) reminders. The *Encoding additional information* strategies are also used to facilitate monitoring. The added information (e.g., flags) makes prospective messages visually distinct.
3. **Retrieval**. There are no mechanisms supporting retrieval of information related to future actions. Currently, a combination of the *Limiting* with the *Encoding additional information* strategies supports easier retrieval of prospective actions.

Table 3.6 (next page) presents a summary of prospective memory processes (high-level goals), user goals, user actions, and issues encountered by users in performing these actions.

1. For example, most of the field study participants who used Microsoft Outlook did not use its features related to prospective message handling (even if they knew about them). More interestingly, research conducted inside Microsoft corporation indicates the same situation (Cadiz et al., 2003).

High-level User Goals (prospective memory processes - Figure 3.3)	**1. Encode** the intended pending task details (that, when & what)			**2. Monitor:** set reminders to facilitate the pending task's recall (reminders change passive monitoring into active)				**3. Retrieve** the intended pending task details (content)
User Goals (rationale behind user actions)	Encode pending task attributes (content & temporal - additional structure & relationships are made explicit)			Create opportunistic reminding			Create interrupt-driven reminding	Retrieve pending tasks attributes (content & temporal - what&when of intention)
User Actions (strategies employed to achieve goals)	Flag msgs. leave msgs. open	Move msgs. to special location: - categorize by using folders, - spatial loction e.g. on desktop	Move msgs. to calendar	Keep msgs. visible (e.g. use limiting strategies)	Leave msgs. around	Review inbox periodically	Create time-based reminders	Check message location, flag setting, response status, sender, etc.
Issues (problems corresponding to User Actions)	Encoding more details is not possible or requires too much effort	Messages moved to special locations require explicit review action and may remain unnoticed		Requires explicit action, for example to review inbox. Information may be unnoticed			Interrupts are not always effective, because they are: - discrete, - insensitive to user activity, - only time-based (not event-based), if set too early may be forgotten	Requires (at least partial) reprocessing of original message to reconstruct the original intention

Table 3.6. User actions, goals and issues with prospective memory support.

3.4 Summary

The field study presented in this chapter explored handling of prospective information in email. Email is not time "aware", yet it is used to handle messages with various temporal requirements. In particular, messages containing future references need to be kept in the processing loop until they are "due". In handling prospective information, users were found to perform a range of additional actions to compensate for the "missing" email functionality. The study demonstrated individual differences in prospective email handling styles. Two user groups were identified; "one-touch email users", and "accumulate email users". Evidence was also found that handling prospective messages is related to other factors. Specifically, the neatness of participants' office desks was related to transferring prospective information from email. Thus, not every person will benefit in the same way from supporting prospective memory in email. A question was asked in the follow-up user studies: What are the possible sources of these individual differences?

The study provided a better understanding of prospective memory requirements. Based on their analysis, focus of this research turns to supporting monitoring and retrieval of information from prospective messages. The next chapter presents a possible design approach to supporting monitoring and retrieval of prospective information from email messages.

Chapter 4

User Interface Design

"There is no direct path between the designer's intention and the outcome.
As you work a problem, you are continually in the process of developing a path into it, forming
new appreciations and understandings as you make new moves."
Donald Schön, in "Bringing Design to Software" (Ed. Terry Winograd)

"Nothing is brought to perfection on its first invention."
Cicero, "Brutus"

4.1 Introduction

Review of previous email studies (Chapter 2) led to the formulation of the main issues concerning the handling of *prospective* messages. The issues are as follows: 1) dealing with a large volume of messages; 2) manual or mental recreation of relationships between messages; and 3) revisiting prospective messages repeatedly (see Section 2.3.1 in Chapter 2). Results from the field study (presented in Chapter 3) suggested encoding, monitoring, and retrieval as those prospective memory processes, where email support falls short. Chapter 3 described strategies employed by users to compensate for the missing support. This chapter describes two user interfaces that were designed and implemented in the course of this thesis. First, the theoretical motivation and the rationale behind the user interface design is presented. Then, the two interfaces are described in detail.

The discussion starts with high level design requirements, which are based on the three formulated earlier issues concerning the handling of prospective email. Those issues were grounded in current user practices. The requirements are as follows; the user interface should: 1) help to deal with large amounts of messages; 2) make relationships among messages "better visible"; and 3) make message attributes "better visible". These requirements are considered in the context of handling prospective messages.

Section 2.6.2 in Chapter 2 described four types of temporal references that can be contained in email messages. The fourth of those types, the *Message body reference time*, was defined as (a) temporal reference(s) embedded (explicitly or implicitly) in the message body. In general this reference type can be to the past, the present, or the future. The focus of this thesis is on prospective information related to pending tasks, that is, on information referring to the future. The aim is to design user interface that makes temporal relationships among pending tasks attributes "better visible" by making them more perceptually explicit. Such interface would shift some of the information processing load from the user's cognitive system to the perceptual system (Larkin & Simon, 1987). The underlying premise is that a graphical representation may be more computationaly efficient than textual representation. The justification of the expected computational efficiency can be supported by Bertin's taxonomy of seven visual variables and four types of perception (Bertin 1981; 1983). Bertin characterized the following seven visual variables: *size*, *value*, *hue*, *orientation*, *texture*, *shape* and *position*. These variables were called by him the *retinal variables*, because they are perceived quickly and effortlessly across the whole visual field. The four perception styles are: *associative*, *selective*, *ordered*, and *quantitative*. The retinal variables vary in their aptness for the four types of perception. *Shape* is the only variable that does not support *selective* perception (Figure 4.1), in which the viewer's aim is to isolate all instances of a given category.

Figure 4.1. Illustration of *shape* variable which does not permit *selective* perception.
Search target: "6".

In Figure 4.1 (a) the "6" is difficult to locate because the other characters have the same size, value, color, weight, and orientation and differ only in shape. In (b) a redundant *value* cue (bold italic) is added, as a result perception of the "***6***" is much easier.

Figure 4.2 shows a more realistic and complex example where the goal is to find a specific date (May 06, 2004) among other dates. In (a) the date information is encoded in the *shape* of characters. In (b) *position* additionally encodes the order of dates, as a result finding the date is easier. In the latter case, *ordered* perception, in which the viewer determines the relative ordering of values along a perceptual dimension (e.g., a position), provides an additional guidance.

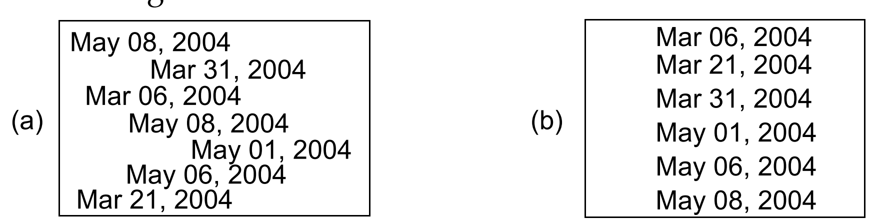


Figure 4.2. Illustration of *shape* and *position* variables and *ordered* perception.
Search target: "May 06,2004".

Figure 4.3 demonstrates *quantitative* perception. In *quantitative* perception, the viewer determines the amount of difference between two ordered values. From the seven visual variables, only *position* and *size* are quantitative. The viewer can, for example, immediately see that one line is twice as long as another (Figure 4.3).

Figure 4.3. Illustration of *quantitative* perception.

Coming back to the more realistic example with dates, the next figure (Figure 4.4) shows a graphical representation in which *position* is used to encode the temporal order of dates as well as their value. Order ranking based on position is immediately obvious. A combination of *quantitative* perception and reading of the date index can be employed to find the date information.

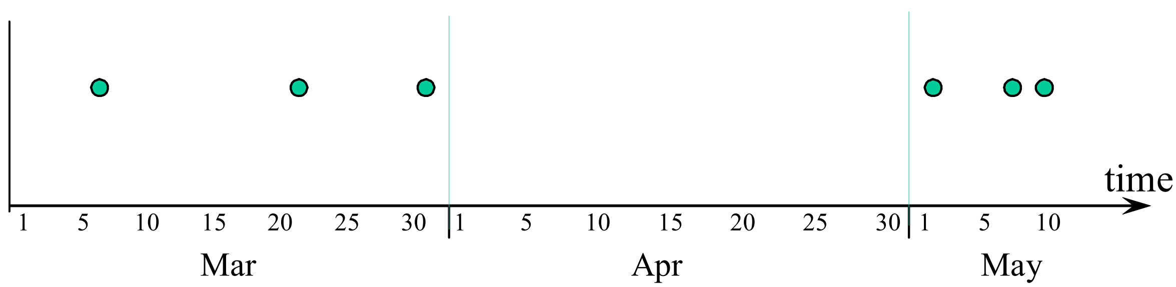


Figure 4.4. Illustration of *position* variable and *quantitative* perception.
This figure represents the same dates as in Figure 4.2.

Putting the preceding concepts together, the next figure (Figure 4.5) shows a graphical representation of pending tasks displaying their temporal attributes along with another attribute (e.g., a person's name). The two dimensional graphical representation provides an overview of pending tasks showing their temporal relationship. The graphical representation affords one to make queries (ask questions). For example, queries can be made about the order of tasks (ordered perception), and the number of tasks in a given time period. It also allows one to ask direct queries on a task's temporal attributes (quantitative perception supported by references to the index). This kind of representation was employed in the user interfaces designed in the course of this thesis to display temporal attributes of the pending task (Figure 4.6 and Figure 4.8).

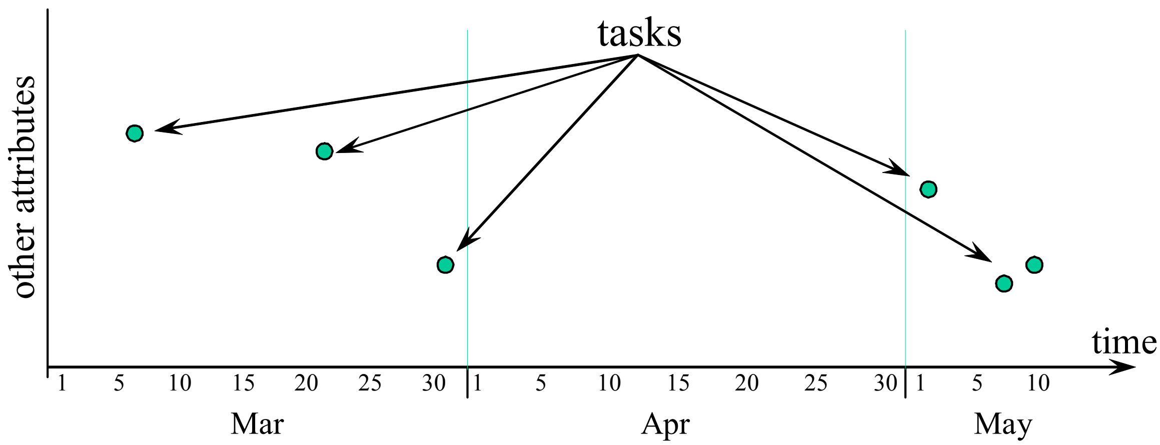


Figure 4.5. Graphical representation of pending tasks.

Visualization of temporal relationships between tasks implies displaying them along a timeline according to their time attribute, that is, according to their scheduled time. Time is represented as a horizontal line[1] with the time arrow running from left to right[2]. The vertical axis is used to distinguish between tasks based on another attribute, for example, on one of the header fields from an email message (Figure 4.5).

The design and implementation process was iterative. There was one major iteration (between the two interfaces) and smaller iterations within the development process of each interface (a short pilot evaluation proceeded each study). The major lessons learned in each iteration were then used in guiding the re-design of the interface. The two interfaces, TaskView and WebTaskMail, are described in detail in the following sections.

1. There are two main ways people conceptualize time. The oldest concept of time was cyclical, a more modern concept is linear (Aschersleben et.al., 1999; Roeckelein, 2000).
2. The visual representation of time in space is also reflected in our language. For example, in the use of "before", "after" to describe spatial and temporal relationships. (Time-spatialization hypothesis Vandierendonck & De Vooght, 1998)

4.2 TaskView User Interface

The TaskView interface was based on TimeStore described earlier (in Section 2.6.2, Chapter 2). TaskView uses essentially the same graphical representation (Figure 4.6), however the use of the timeline in the two systems is different. TaskView employed a timeline to show the temporal references embedded in the messages, while TimeStore used timeline to show message arrival time. The goal of the two interfaces was also different. In TaskView, it was the management of pending tasks, while in TimeStore, it was the retrieval of messages from an email archive.

Tasks embedded in messages are represented in TaskView by small icons on a two-dimensional grid with temporal information shown on the horizontal axis and other task attributes shown on the vertical axis. Other task attributes include sender, subject, or keywords extracted[1] from the message body. User can select which of these attributes is shown (only one attribute at a time can be shown). TaskView provides navigation backward and forward in time, by year, month, and day. Users can zoom-in and zoom-out in time, switching between one year, three months, one month, or one day views. The message body can be viewed by double clicking on the corresponding task icon.

1. Keywords were extracted by using Extractor, software from National Research Council (Turney 2000).

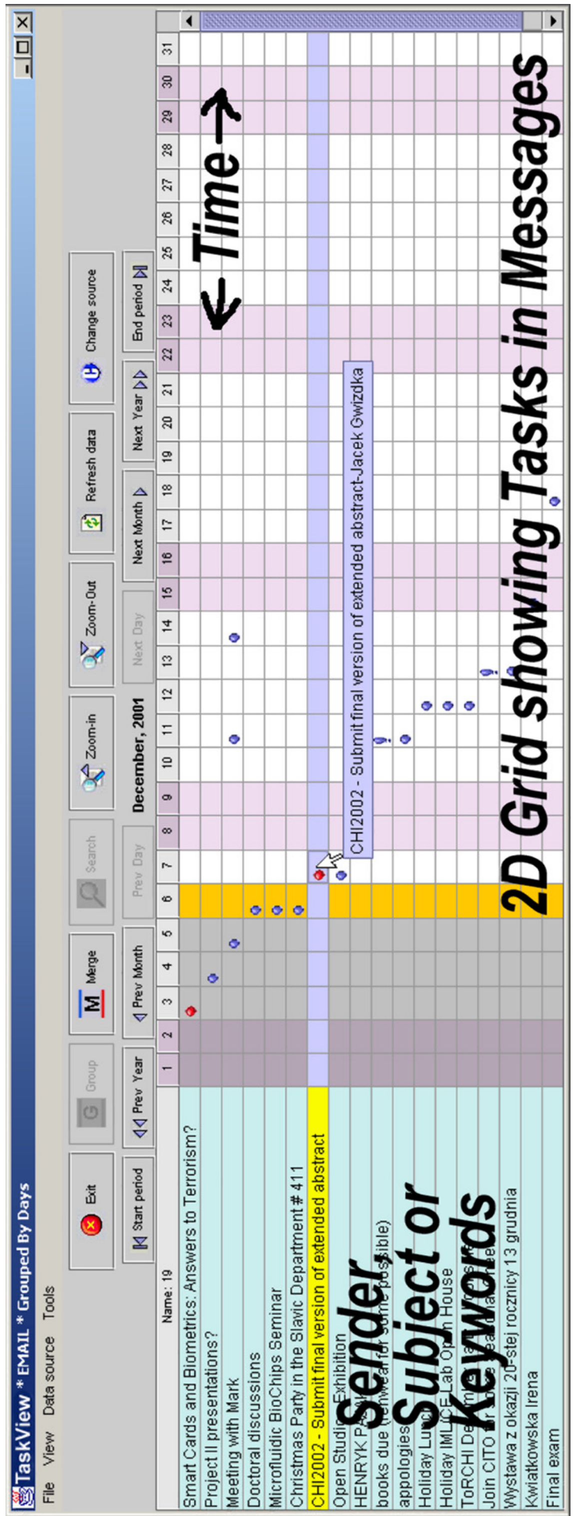


Figure 4.6. TaskView interface—Monthly view with pending tasks sorted by time.

TaskView presents only active messages, that is, messages with future references containing pending tasks. As can be seen from Figure 4.6, the visual representation allows for a one-to-many mapping between a message and tasks (e.g., the third row from the top "Meeting with Mark"). For the purpose of this research however, a simplifying assumption was made that one message corresponds to one task[1].

The analysis of email handling in the context of prospective memory processes, presented in Chapter 3, suggested that monitoring and retrieval are insufficiently supported in email. Figure 4.7 shows TaskView elements that provide better support for monitoring and retrieval of prospective information. Monitoring and retrieval are easier, because pending task dates are made more perceptually explicit, and its reading is more efficient in terms of cognitive effort or mental computations required (Larkin & Simon, 1987).

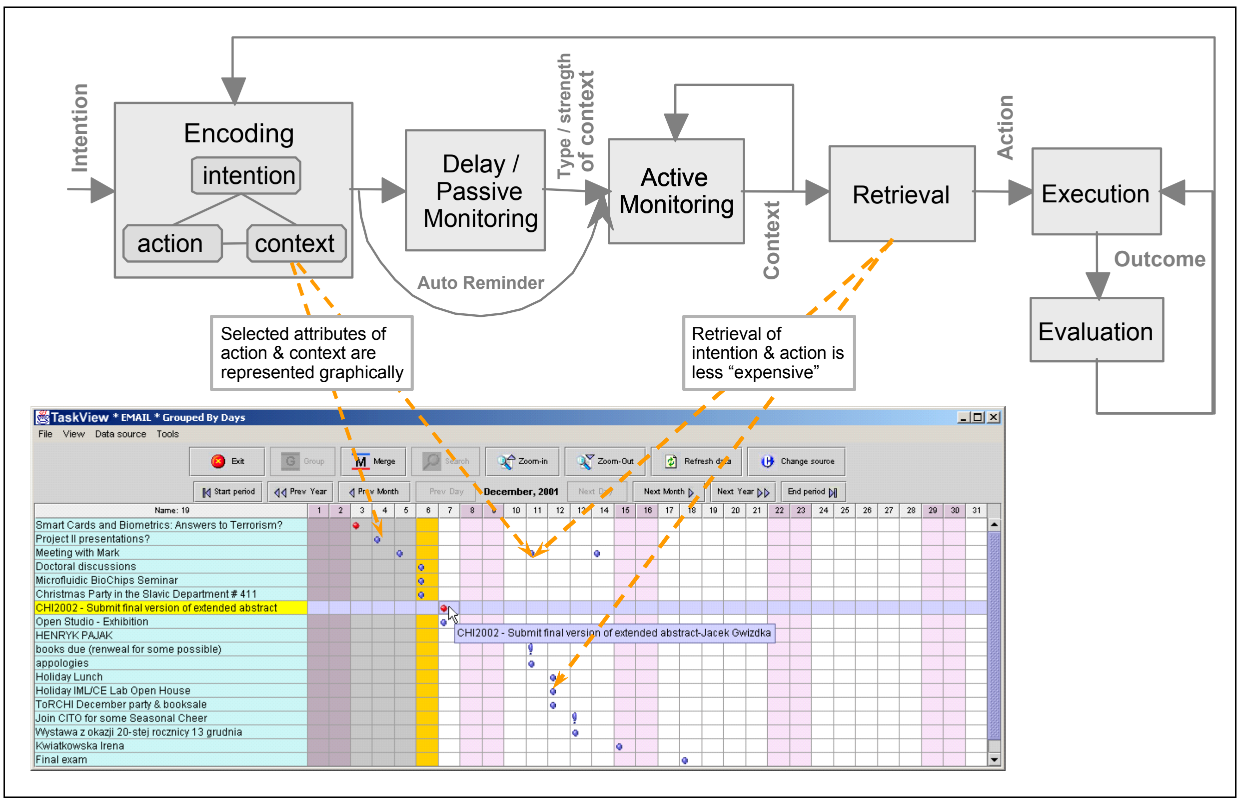


Figure 4.7. Support for prospective memory processes in TaskView.

1. Although there are no supporting statistics, there is an anecdotal evidence that some users respond only to one point expressed in a message. It may be the first point, or the easiest point.

TaskView was implemented in Java 2, as a standalone Java application. In order to import email messages into TaskView, MAPI (mail application programming interface) services were used to communicate with Microsoft Outlook or Qualcomm Eudora email programs.

4.3 WebTaskMail User Interface

Design of the second email interface, WebTaskMail, was an iteration of the TaskView interface (presented in the previous section). Design of WebTaskMail was informed, in part, by findings from the first user study, which is described in Chapter 5. The study compared TaskView's time-based representation of messages/pending tasks with a more standard user interface (the Microsoft Outlook inbox) with respect to efficiency and effectiveness of information finding in email messages. As it is described in Chapter 5, the user study results indicated the need for better visual integration of email header information with task attributes. Thus, one of the aims of the interface redesign was to achieve a better integration. A more detailed discussion can be found in the first section of Chapter 6.

The WebTaskMail interface (shown in Figure 4.8) combines the familiar timeline/calendar view of pending tasks' temporal attributes with the other message attributes (sender, the subject line, and the date sent). This user interface differs from the previous also in other ways. It introduced the notion of events and to-do's, and start- and end-dates of tasks. It also provided additional features supporting handling a larger amount of messages by creating views, and thereby limiting the amount of displayed information.

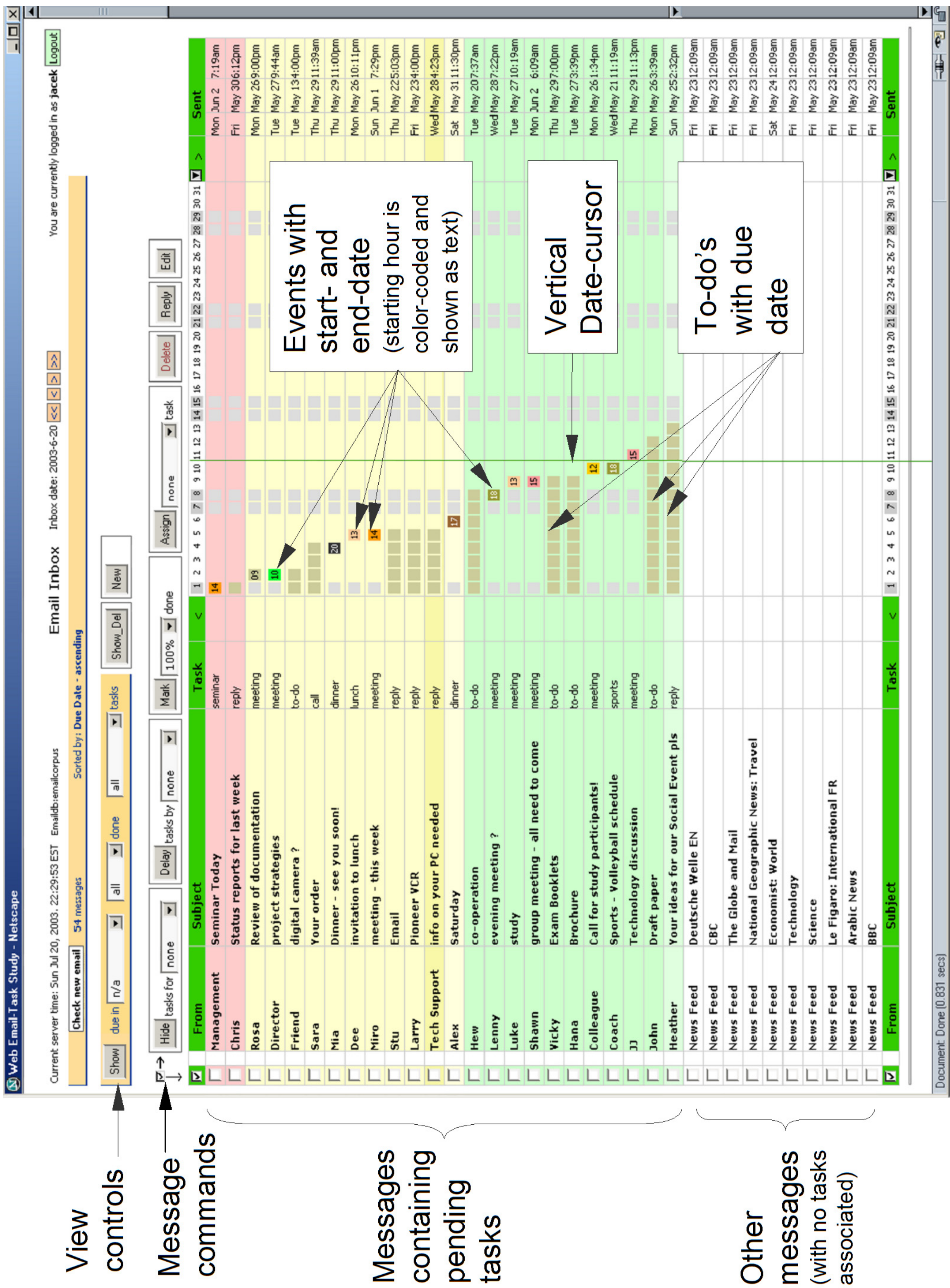


Figure 4.8. Screenshot of WebTaskMail user interface. Showing one month view.

4.3.1 Graphical Message and Task Representation

Along with familiar email message header fields (on the left: From, Subject, Date Sent), WebTaskMail shows graphically (on the right) the tasks, and their temporal attributes, that are associated with messages. A distinction is made between two generic types of tasks: events and to-do's. Events are characterized as being scheduled to start and finish at specified times. They have a fixed Start- and End-date. An example of an event is a meeting, a lunch, or a doctor's appointment. To-do's are characterized as having a deadline (End-date), but no Start-date.

Events are represented by single squares (or bars for multiple day events), while to-do's are represented as bars (or single squares if the deadline falls on the next day) (Figure 4.9). The squares and bars are positioned horizontally according to their Start- and End-dates. The basic view shows a month worth of tasks. Color-coding of event squares represents Start-hour. In addition, two digits representing the starting hour are shown inside each square. Providing this information gives an at-a-glance overview of tasks. Users do not have to switch to a different view (e.g., a day view) to get an overview of their daily, weekly, and monthly schedules.

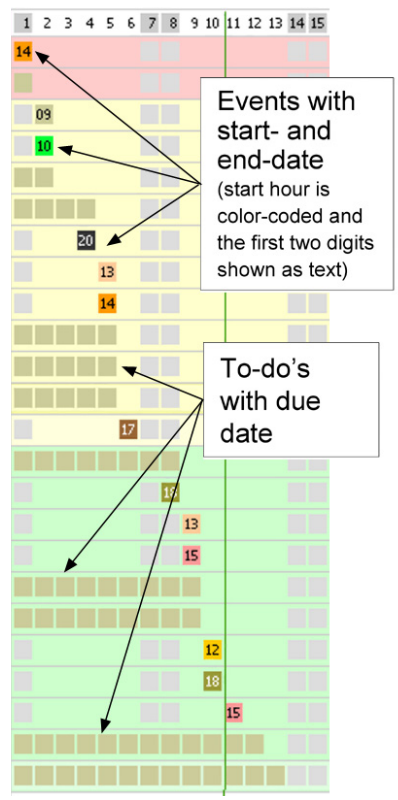


Figure 4.9. WebTaskMail close-up showing squares representing events & to-do's.

Like the traditional inbox, each row represents one message. The background color encodes how far in the future an event is scheduled, or when a to-do is due. A light-red background represents today, light-yellow—the current week, and light-green—the following weeks. Past due to-do's are shown as red bars on a gray background. The past-due to-do's do not disappear until they are marked explicitly as completed. The visual representation allows for a one-to-many mapping between a message and tasks. However, only the one-to-one mapping was used in the user studies.

A text field called "Task"[1] was added to WebTaskMail. The "Task" field contains an optional keyword describing the task associated with the message. The keywords can be added manually from a pre-defined, controlled vocabulary.

4.3.2 Support for Information Management in Inbox

WebTaskMail provides several operations that can be applied to messages containing tasks. A task can be delayed by a specified period of time; the completion status of a task can be marked; and the Task keyword can be assigned. These operations can be performed on a single message or on groups of messages. Task marked as fully completed have a distinct visual appearance. Functions and features that WebTaskMail provides to support information management in the inbox include:

- Temporary message hiding (a similar feature was introduced by Ishmail (Isbell et.al., 2002)). Single messages or groups of messages can be hidden for a specified period of time, after which they will automatically reappear in the inbox. WebTaskMail introduces message hiding based on temporal task attributes. The period of time, for which a message is hidden, depends on when an event starts, or on a to-do's deadline.
- Message expiry time. A date can be associated with messages after which they will automatically disappear from the inbox. A class of messages can be defined (e.g., messages from news sources) to have an expiry time set automatically, based on when the messages arrive.
- Messages in the inbox can be sorted by any of the displayed columns, including Start- and End-dates.

1. This field is similar to Microsoft Outlook's "Follow Up Flag".

- A message store, implemented using a relational database (MySQL). This solution enables flexible creation of views based on email message attributes. The user interface controls were defined for an easy creation of several views based on pending task attributes. A view can be created based on a combination of 1) task due dates, 2) task completion status, and 3) task keywords. Deleted, hidden and expired messages can be accessed through special views.

Since our research is focused on processing current email messages, it does not address archival aspects of email and therefore the system does not provide email folders.

The new email user interface was implemented and deployed using web technologies. Namely, the program was written in HTML, JavaScript, and PHP (v4.3). The client code (HTML/Java Script) was run in Netscape 7.1 Internet browser on a Microsoft Windows 2000 Professional desktop computer. The server code (PHP) was executed by Apache v1.3.26 web server under Sun Microsystems SunOS 5.8 operation system. The server-side code communicated with relational database implemented in MySql version 11.18. The database was used to store email messages, as well as to log user interaction with the interface. Web technology allows WebTaskMail to be used without the need to install the prototype software on users' own computers, thus simplifying use of the system in field studies.

4.4 Summary

A set of requirements for visualizing pending tasks was formulated based on the results obtained in the previous study (Chapter 3). Two email user interfaces were then developed to (partially) address these requirements. The TaskView interface showed pending tasks arranged on a two-dimensional grid. The WebTaskMail interface, developed subsequently also showed a timeline, as well as provided vertical *reading line*, and additional space for message headers. The next two chapters report on two user studies that evaluated each of the two presented user interfaces.

Chapter 5

TaskView — User Study #1

It is a good morning exercise for a research scientist
to discard a pet hypothesis every day before breakfast.
It keeps him young.
Konrad Lorenz, "On Aggression"

The great tragedy of Science - the slaying of a beautiful hypothesis by an ugly fact.
Thomas Henry Huxley, Collected Essays

5.1 Introduction and General Methodology

Chapter 4 presented general principles and details of two user interfaces designed in the course of this thesis. The interfaces embody expectations about what pending task information should be displayed and how. The underlying premise is that graphical presentation of temporal information related to pending tasks is "better" than textual presentation, because the former is more perceptually *direct* than the latter (and thus off-loads cognitive processing).

Two user studies were undertaken to explore the research questions initially posed in Chapter 1, and to support or refute the claims embodied in the visual representations. The first goal of the user studies was to evaluate whether the designed visual representation of prospective messages (pending tasks) did indeed help users. For the purpose of this research, "to help users" is being defined as "to make users more efficient and effective". Achieving the first goal involved assessing user performance on a task carried out by means of two user interface variants that represented temporal attributes of prospective messages differently. The two interfaces were informationaly equivalent but not computationaly equivalent (Simon, 1978; Larkin & Simon, 1987). In one interface variant, pending task dates were represented graphically (as described in Chapter 4)—this interface was called UI-Visual. In the other interface variant, dates were displayed as text—this interface was called UI-Text[1].

The second goal of the user studies was to examine the differences in performance between users. Chapter 2 described individual differences in human-computer interaction, focusing on differences which can be attributed to human cognitive abilities, while the field study presented in Chapter 3 demonstrated individual differences in *prospective*

1. The two user interfaces differed in terms of the number of graphical and textual elements used. The UI-Visual interface employed more graphical elements in the representation of pending task dates, while the UI-Text interface employed more textual elements.

email handling styles. One could reasonably expect between-user differences in performance on email tasks.

Visual representations *mediate* the user tasks performed in email. The representations define what information is immediately available, and influence the effort required to perform different *queries* on that information. The above definition of “to help users” does not constrain the user task[1]. The domain of user tasks of interest to this research has been earlier defined as handling prospective messages (that is messages referring to the future). For the studies reported in this chapter, and in Chapter 6, the domain of interest was further narrowed to one aspect: finding information related to prospective messages that carried pending tasks (tasks intended to be performed in the future).

I now turn to a general description of the methodology employed in the user studies, first describing the elements common to both studies. The details of each study are presented later (in Section 5.3 in this chapter and in Section 6.3 in Chapter 6). The studies were designed as task-based evaluations and were conducted as controlled studies in a laboratory environment. A controlled laboratory study, rather then a field study, was carried out to be able to measure user performance on the selected task without interference from uncontrollable factors found in user environments. In doing this, care was taken to create a relatively realistic user task, which maintains at least some degree of ecological validity.

The goals of the study required comparing differences in the performance of each user for two variants of user interface, and comparing differences in performance between groups of users. A task-based evaluation was chosen because it permits comparisons between users and systems. In the context of email, an evaluation approach based on realistic benchmark-tasks was proposed by Neuwirth et al. (1998). In this approach, users’ performance is measured on benchmark-tasks carried out using different email

1. “Task” as used in this thesis has two meanings. 1) to refer to tasks embedded in messages (*pending tasks*); 2) to refer to the tasks users performed in the study (*user tasks*).

systems. A related methodology was advocated by Whittaker et al. (2000b) as a general framework for comparative evaluation in HCI. Two components are central to this approach: *reference tasks* and associated evaluation *metrics*. Reference tasks are core tasks that are independent of specific applications, and that commonly occur among different types of systems. Although the subject of this research is limited to one kind of interactive systems, it will be argued that the selected user task is a good candidate for a reference task. Choices made for the user task and metrics will be justified by using criteria described by Whittaker et al. (2000).

5.1.1 Choice of the Candidate Reference Task and the Evaluation Metrics

5.1.1.1 The Reference Task: *Information finding in email*

Why is *information finding in email* a good candidate for a reference task? The following criteria were proposed for selecting a reference task (Whittaker et al., 2000): 1) real, 2) frequent, *or* 3) critical. Numerous studies of email use have demonstrated that email users frequently keep information in their inboxes and email folders. Findings from my own field study (presented in Chapter 3) showed that users, who keep email messages referring to the future in their email, tend to visit their inboxes more often. All these operations require email users to find information in messages. The task is *realistic*. The selected user task is performed quite frequently in email handling sessions, often as a part of more complex email activities. The task is *frequent* and it is growing in frequency as email activity increases.

5.1.1.2 The Metrics

The growing awareness and the need for effective and efficient email handling (Jackson et al., 2001) led us to define the following types of metrics: 1) ability to find information in inbox (success of task completion), 2) accuracy of the answer; and 3) time to find the information. These metrics are general; they apply to the information finding task not only in the context of the studied application.

5.1.2 Description of the User Tasks

As noted earlier, the main user task was to find information related to pending tasks in email messages. The task was designed to simulate a real email session in which users are looking for information in email messages based on partial information. For example, one may want to find out how many meetings (described in email messages) are scheduled for next week, or one may remember that there is a lunch in two weeks, but not the exact date of that lunch.

The user task involved finding information about pending tasks associated with incoming messages. No tasks related to outgoing messages, to which, for example, a reply is expected/needed, were used. This does not limit generalization of the study results to both incoming and outgoing messages, since outgoing messages are represented in the same way as incoming, and no differences in performance on information finding task are expected.

The information finding task was driven by multiple-choice questions displayed on a computer screen, along with the choice of possible answers. The questions were designed to refer to *two* different types of target information: 1) dates associated with pending tasks, and 2) sender or subject information contained in message headers. The two types of target information were chosen to compare performance on the two kinds of user interfaces. By design, presentation of the first type of information differed between the two user interfaces, while presentation of the second type of information did not. Thus, it was expected that answering questions about dates would involve a different information finding strategy in the text interface than it would in the visual interface. In contrast, search for information in the message header was expected to be less affected by differences between the text and visual interfaces. The two information types were used to create two categories of questions and two corresponding user tasks (“Header”, “Date”).

Type "Header" questions refer to non-temporal information in the message subject, or sender, header fields. Type "Date"[1] questions referred to pending tasks' temporal information, for example, to a meeting date, to a to-do deadline, or to the number of events scheduled in a specified period of time. In the second user study (Chapter 6), a new type of task was added: "Mixed". Type "Mixed" questions referred to *both* types of information (dates and headers) and thus were expected to involve mixed user strategies.

5.2 Expectations and Hypotheses

The first experimental expectation was based on the belief that visual representation of pending task information will be beneficial to email users. A specific hypothesis was formulated:

Efficiency Hypothesis. Efficiency as measured by performance time to complete information retrieval tasks will be higher overall in the UI-Visual (TaskView—Figure 4.6) than in the UI-Visual condition (Outlook—Figure 5.1).

It was expected that high levels of cognitive ability would generally increase the efficiency of pending task information retrieval, but that the effect of cognitive ability would be reduced with the TaskView interface. Thus three specific hypotheses were formulated (one for each of the cognitive abilities):

Flexibility of Closure Hypothesis. Participants with low level of flexibility of closure (FC) will perform worse (in terms of efficiency) in UI-Text (Outlook) than in UI-Visual (TaskView). People in low flexibility of closure group were expected to be slower on the "Date" task in the UI-Text interface because this task required them to do extract textual

1. In the current email programs, pending task dates are not part of the email message header. Thus, the target information in the "Date" task did not refer to message headers. On the other hand, email message headers may contain other kinds of date information (e.g., date sent) which were not used in this study, and to which the "Date" task did not refer. It should be noted, that future email standard may include information referred to in the "Date" questions as a part of email header.

task information from among other textual information. There was no easy perceptual/visual distinction between relevant (task) and non-relevant (non-task) information, both of which were presented in text.

Visual Memory Hypothesis. Participants with low visual memory (VM) will perform worse (in terms of efficiency) in UI-Visual (TaskView) than in UI-Text (Outlook). People with low visual memory were expected to be adversely affected by the more visual interface, because it required them to switch between different views (e.g. to navigate in time), and thus to hold more visual information in memory than when using the UI-Text interface.

Working Memory Hypothesis. Participants with high working memory (WM) will perform in UI-Text (Outlook) better than those low on working memory, while no such differences will be observed in UI-Visual (TaskView). This hypothesis derives from the role that working memory serves as an input buffer and from the expectation that the Outlook interface requires more information to be kept in the input buffer than does UI-Visual.

5.3 Study Design

5.3.1 Method

A mixed factorial design was used with user interface as an independent within subject factor (2 levels: Outlook and TaskView). There were two sessions. Each subject used a different interface in each session. The design was balanced with respect to the order of interface use. There were also three independent, between subject factors based on three measured cognitive abilities (flexibility of closure, working memory, and visual memory). Scores for each of the cognitive abilities in the experimental sample were split at the median into two groups (i.e. low versus high levels of the ability). For each of the three cognitive abilities, these two levels of the ability (low vs. high) were defined as a pseudo-factor in subsequent analyses of the experimental data. The additional factor of "Task" was defined based on the type of question users were answering. The two question types categories (“Header” - “H” and “Date” - “D”) were described earlier.

5.3.2 Apparatus

Two email programs were used in the experiment: Microsoft Outlook and TaskView. Microsoft Outlook served as a benchmark email interface (Figure 5.1). In Outlook pending task dates were displayed as textual fields in a familiar tabular mail folder view. TaskView interface was described earlier in Chapter 4 “User Interface Design”. In the TaskView interface, pending tasks were represented on a two-dimensional grid, as shown in Figure 4.6. The programs were installed on a desktop PC in the experimenter's office. Participants' interaction was recorded using the Camtasia software for capturing activity on the computer screen. Email inboxes in both programs were populated with the same 44 messages that had pending tasks associated with them. These 44 prospective messages were selected from a corpus of 128 emails that were collected from six people whose roles included: a senior graduate student, a start-up company employee, a usability consultant, a project manger, and a faculty member. All messages were sanitized by removing information identifying people and companies. The sanitization procedure included changing the names of email senders and of people being referred to in message text and in subject lines.

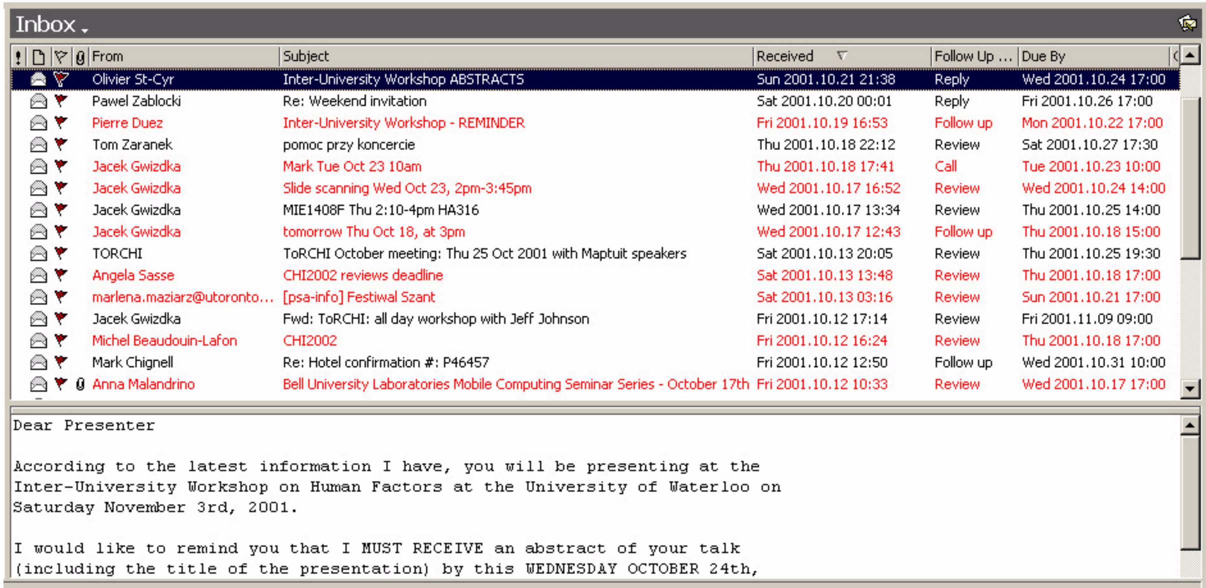


Figure 5.1. Microsoft Outlook interface[1].

A set of 43 questions (see Section E.1 in Appendix E) about pending tasks contained in the messages was created from a set of queries that people ask their calendars and to-do lists. This set of queries was generated based on information collected from two people (one was a manager of a architecture department in a major national bank, the second was a manager in a large telecommunications company). As described earlier, the questions were categorized into two types: “Header” and “Date”.

5.3.3 Participants

21 people participated in the experiment. 18 participants were university graduate students (7 Master students and 11 Ph.D. students), and 3 participants were full-time employees from outside companies or government agencies. There were 7 females and 14 males. Participants were screened for at least moderate use of email and for the use of email to receive task information. On average, participants had used email for 6 years. Participants were paid $30 for their time ($10 per hour).

1. In addition to the fields present in the standard Outlook inbox folder view (various flags, From, Subject, and Received), two additional fields (Follow Up By and Due By) that correspond to the temporal information that is presented graphically in the TaskView interface (Figure 4.3)

5.3.4 Procedure

The study consisted of four on-line questionnaires and two sessions conducted in the experimenter's office. The sessions were spread at least 2 days apart, and no more than 7 days apart. Participants used a different email interface in each session and were randomly assigned to the session order. Each session lasted between 1 hour to 1.5 hours.

Before coming to the first session, participants filled out an on-line survey containing demographic and email-habit questions. Each session consisted of study protocol explanation, user interface training, and the main task. The main task was to find information about pending tasks in email messages. Information finding was driven by multiple-choice questions posed to the participants. 21 questions were drawn randomly from a larger set of 43 questions (listed in Appendix E). After the main task was completed, two cognitive tests were administered. Different tests were administered in each session. The tests used are listed in the next section. In the "TaskView" session, after using the new interface, participants filled out a subjective preference questionnaire. At the end of each session participants were asked to freely recall information about pending tasks which they had looked up in email messages earlier in the session. After each of the sessions participants filled out an on-line questionnaire containing the same set of questions as they answered during the session (the order of questions was randomized).

5.3.5 Measures

Experimentally controlled measures:

1. Two levels of user interface: UI Text (Microsoft Outlook) and UI Visual (TaskView);
2. Two tasks: *Header* (H) and *Date* (D).

Original independent, between subject measures:

1. Cognitive abilities were measured using the Factor-Referenced Kit of Tests (Ekstrom, 1976). Flexibility of closure was assessed using the CF-2 test; two visual memory tests were administered: 1) visual memory for shapes was assessed using the MV-1 test; 2) visual memory for location on 2D maps was assessed using the MV-2 test. Working

memory was measured using the auditory digit span test (MS-1). The range of scores for the study population is shown in Table 5.1;

2. Demographic data and self-reported email use data, focusing on handling of pending tasks, was collected using an on-line survey.

Statistic	Cognitive ability test			
	CF-2[a]	**MV-1[a]**	**MV-2[a]**	**WM**
Mean	58.7%	69.5%	65.8%	6.4
Std. dev.	13%	16%	30.5%	0.9
Min. value	32%	44%	0%	4.5
Max value	80%	100%	100%	8.0
Number "Low"[b]	10	10	10	9
Number "High"[b]	11	11	11	12

Table 5.1. Range of cognitive abilities for the study sample[c].

a. Test results are reported as percentage scores.

b. Number "Low" & "High" are the numbers of people in the study sample who were, respectively, below or above and equal to the median value of each cognitive ability.

c. Statistics for other populations provided by the test authors are shown in Appendix B.

Derived independent, between subject measures (treated as pseudo factors):

From the Factor-Referenced Kit of Tests:

1. FC[1] - scores on CF-2 grouped into two levels by median (low-high)
2. VM1[1] - scores on MV-1 grouped into two levels by median (low-high)
3. VM2[1] - scores on MV-2 grouped into two levels by median (low-high)
4. WM - scores on MS-1[2] grouped into two levels by median (low-high)

Dependent, within subjects measures:

1. Efficiency, as measured by the time taken by participants to answer questions;
2. Effectiveness, as measured by ability to find the correct information (answer);
3. Subjective evaluation of both interfaces.

1. Note: abbreviations correspond to full names (e.g., VM - Visual Memory) and are reversed test names.
2. The scoring used on MS-1 differed from the originally suggested by the reference kit authors'. A different scoring scheme was used to obtain scores reflecting directly the working memory span.

5.4 Results

The analysis began with an examination of the three-way ANOVA interactions between each of the three individual difference factors on the one hand, and the UI and Task factors on the other. None of the three-way interactions was significant (F approximately equal to 1 for short term memory and F < 1 for both flexibility of closure and visual memory).

5.4.1 Order Effect

There was a significant order effect of experimental sessions on performance time ($F(1,19)=6.6$, $p=.019$, $\eta^2=0.26$). Participants who used the visual interface first, performed the tasks slower (37s per task on average) than in the other three combinations of interface and its order (Table 5.2). The textual interface was familiar to all participants[1]. This effect may be thus attributed to heaving to learn the new, visual interface and the experimental task at the same time (in the first session). This hypothesis is supported by the data from the second session, where participants who used UI Visual, that is, those who after learning the task in the first session were now learning the visual interface, performed slower than the other group in the second session (33.7 vs. 30s). In order to consider these effects explicitly, most of the following analyses report the results from the first and second session separately.

	1st Session	2nd Session
UI Text	35	33.7
UI Visual	37	30

Table 5.2. Order effect of experimental sessions (UI) on performance time (seconds).

1. 16 out of 21 used Outlook (perhaps in addition to other email program), 1 used Eudora, and the remaining 4 used web-based mail. In all those cases, they were familiar with the textual email inbox.

5.4.2 Effects of User Interface Design

The subsequent analyses were organized according to the study goals. First, I tested whether the design intervention incorporated in the TaskView interface was successful. (That is, whether study participants performed the experimental tasks more efficiently on TaskView interface.)

As explained above, the analyses were performed separately for each study session[1]. Two-way interaction between UI and Task was assessed using ANOVA. A significant interaction was found in each session (Session 1: $F(1,17)=5.2$, $p=.036$, $\eta^2=.235$[2]; Session 2: $F(1,17)=11.8$, $p=.003$, $\eta^2=.41$). The interaction was robust, and had the same direction in both sessions. The biggest difference was found for UI Visual, where the "Header" task required significantly more time (48.5s and 44.7s in 1st and 2nd sessions respectively) and was the slowest of all four UI * Task combinations, while "Date" task was the fastest (29s and 23.1s in 1st and 2nd sessions respectively) (Figure 5.2). This interaction should be considered in the context of the main effect of Task, which was found as part of the same analysis. (Session 1: $F(1,17)=22.7$,$p<.001$, $\eta^2=.571$; Session 2: $F(1,17)=32.35$, $p<.001$, $\eta^2=.656$). Task "Header" was significantly slower in both sessions (43.5s & 39.3s in 1st and 2nd session respectively), while task "Date" was faster in both sessions (30.3s & 25.9s in 1st & 2nd session).

1. In the analyses of separate sessions that were carried out, UI became a between-subject factor.
2. η^2 refers to the partial ETA squared as reported by SPSS, the proportion of variance (PV) that estimates the size of an effect (Murphy et al. 1998). See also Glossary.

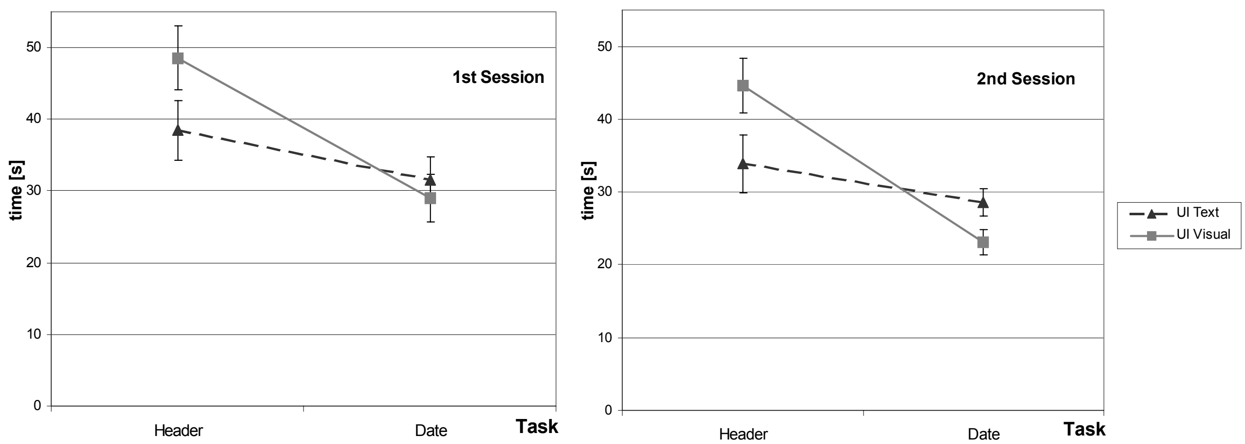


Figure 5.2. Effects of interaction UI * Task on performance time in both sessions.

In the second session, when it could be assumed that the task-learning phase was completed, task "Date" was significantly faster in TaskView than in Outlook (23.1s vs. 28.6s). Therefore, the goal of better supporting this type of tasks was achieved. In contrast, task "Header" was significantly slower in TaskView than in Outlook (44.7s vs. 34s). This was an unforeseen result, as I expected that efficiency of performance in TaskView would not be worse than in Outlook. Possible reasons will be discussed at the end of this chapter.

5.4.3 Effects of Cognitive Abilities

The effects of cognitive abilities were tested using separate two-way analyses of variance with the cognitive ability, and, either the type of interface or the task, as the two factors. In the first case, it was a question of understanding the factors underlying the usability of an interface. Which population group will benefit from the interface? Which group will be affected adversely? In the second case, it was a question of understanding the demands of different tasks.

5.4.3.1 Working Memory

The interaction between working memory (WM) and task was found to be significant in the first session[1] ($F(1,19)=9.1$, $p=.008$, $\eta^2=.349$), but not in the second. There was a significant difference in performance time for the "Header" task, with participants low on WM performing slower than participants high on WM (50s vs. 40s) (see Figure 5.3).

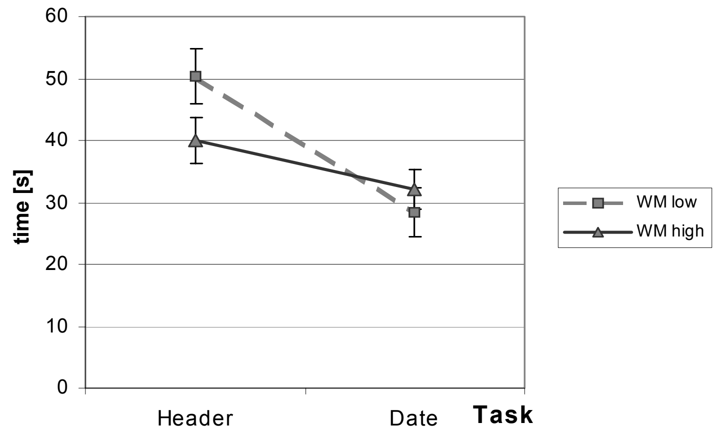


Figure 5.3. Effect of interaction WM*Task on time in the first session.

A significant interaction was also found separately for the "Header" task in the first session between working memory and UI ($F(1,17)=4.8$ $p=.042$, $\eta^2=.221$). Participants who were low on WM performed significantly slower (63s) on the UI Visual (Figure 5.4).

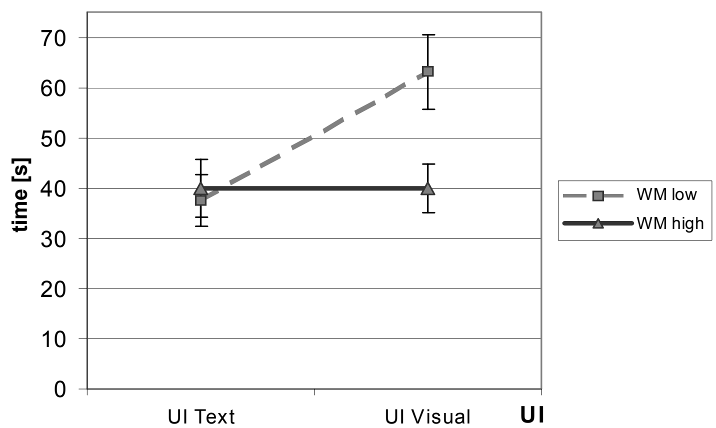


Figure 5.4. Effect of interaction WM*UI on time in the 1st session (for task "H").

These two results taken together suggest that the level of WM affected performance on task "Header", especially in the TaskView interface. Since these WM-related results

1. There was also a similar effect for both sessions together. Both session effects (within subjects design) are not being reported here, because due to the order effect they are difficult to interpret (unless the same effect appears also in the 1st and in the 2nd session separately).

appeared only in the first session, one can infer that they stem from the role of working memory in learning the Visual interface and task “Header”.

5.4.3.2 Flexibility of Closure

The interaction between flexibility of closure (FC) and user interface was found to be significant in the second session (Session 2: $F(1,17)=6.32$, $p=.022$, $\eta^2=.271$) (Figure 5.5). A significant interaction between FC and UI was found for the “Date” task (Session 2: $F(1,17)=10.14$, $p=.005$, $\eta^2=.374$) (Figure 5.6).

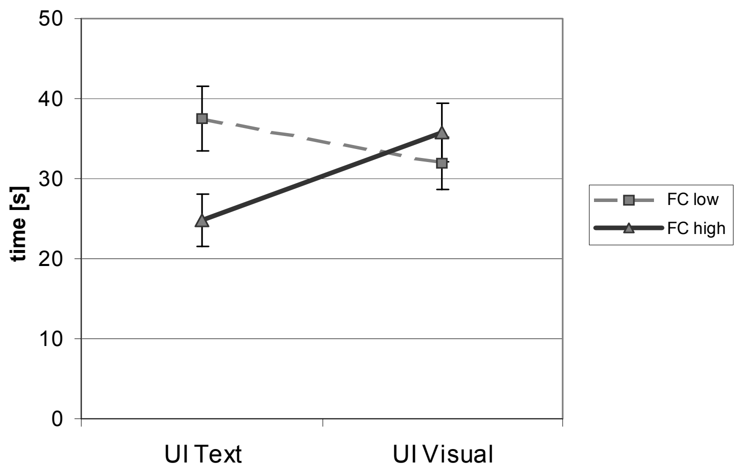


Figure 5.5. Effect of interaction FC*UI on time in the second session.

For the “Date” task, there was also the main effect of FC on performance time (in both sessions), where participants low on FC were overall slower. In Session 1: low FC 35.5s, high FC 25.1s ($F(1,17)=5.15$, $p=.037$, $\eta^2=.23$); Session 2: low FC 28.8s, high FC 22.9s ($F(1,17)=5.5$, $p=.031$, $\eta^2=.244$).

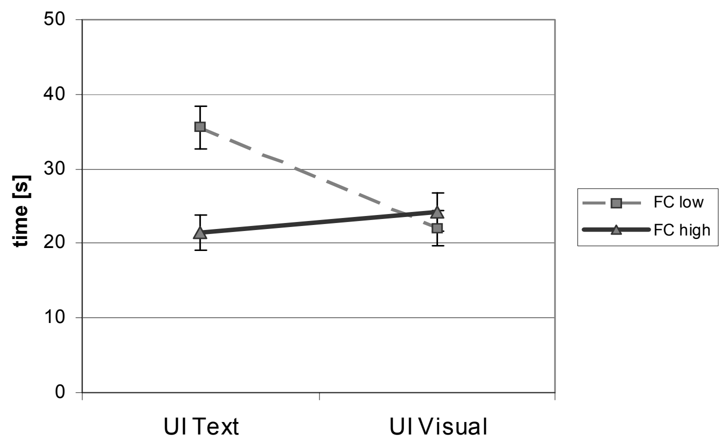


Figure 5.6. Effect of interaction FC*UI on time in the 2nd session (for task "D").

As can be seen from Figure 5.6 performance of people low on FC was adversely affected by the textual interface and the "Date" task. Performance of people high on FC on task "Date" was not affected. This result indicates that extracting date-related information is indeed easier in the TaskView interface, which was designed for that purpose.

5.4.3.3 Visual Memory

The interaction between visual memory measures (memory for shapes—VM1, and memory for location on a 2D map—VM2) and task was found to be significant in the second session (for VM1: $F(1,17)=4.17$, $p=.058$ (borderline) — Figure 5.7, $\eta^2=.196$; for VM2: $F(1,17)=5.58$, $p=.030$, $\eta^2=.247$ — Figure 5.8).

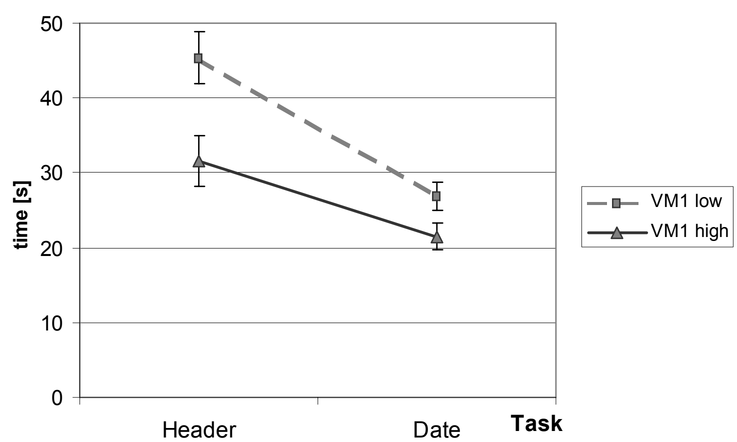


Figure 5.7. Effect of interaction VM1*Task on time in the second session.

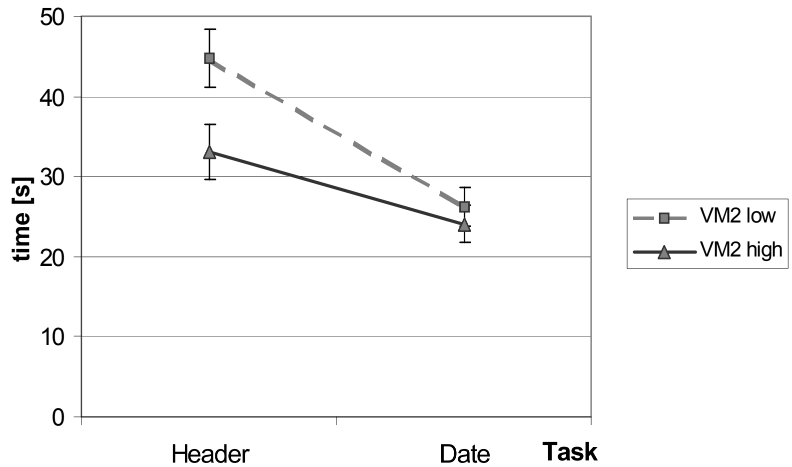


Figure 5.8. Effect of interaction VM2*Task on time in the second session.

There was also a main effect of VM1 on performance time (Figure 5.9), where participants low on VM1 were overall slower. In Session 1: low VM1 40.8s, high VM1 29.8s ($F(1,17)=6.5$, $p=.021$, $\eta^2=.277$); Session 2: low VM1 36.1s, high VM1 26.5s ($F(1,17)=8.48$, $p=.010$, $\eta^2=.333$).

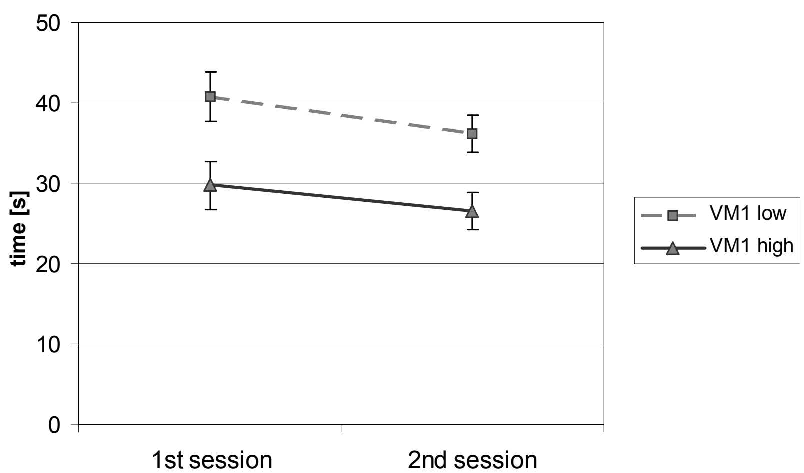


Figure 5.9. Main effect of VM1 on performance time in both sessions.

As can be seen from Figure 5.7 and Figure 5.8, performance on the "Header" task in the second session (after task learning was completed) was affected by the level of the two cognitive measures related to visual memory (VM1 and VM2), which were tested in the study. In both cases, people low on VM1 and VM2 performed significantly slower than those high on VM1 and VM2. "Header" task required to switch between displaying sender versus subject information.

5.4.3.4 Summary of Cognitive Ability Effects

The main quantitative results are summarized in Table 5.3. In the first session, people with low working memory (WM) were disadvantaged for the "Header" task (H) in the TaskView interface. In the second session, people with low flexibility of closure (FC) were slow on the "Date" (D) task when using the Outlook Inbox interface, while people with low visual memory (VM) were disadvantaged on the "Header" task in both user interfaces.

Cognitive Ability	Disadvantage	
	1st Session	2nd Session
FC		Low FC - slow on Task D in UI Text
VM		Low VM - slow on Task H
WM	Low WM - slow on Task H in UI Visual	

Table 5.3. Summary of "disadvantages" for people low on each tested cognitive ability

In contrast to the results for performance time, there were no significant differences in accuracy across the various combinations of the experimental factors.

5.5 Discussion

5.5.1 Interface Design and Tasks

The TaskView interface led to better performance for the "Date" task. At the same time, this study showed the limitations of the current version of this interface. The benefits on performance time were observed for the "Date" task only, while performance for the "Header" task was actually worse in TaskView than it was for the Outlook Inbox interface. The *Efficiency Hypothesis* was thus confirmed only for the "Date" task. An observed order effect, that was attributed to learning of the new TaskView interface and task, cannot fully account for this effect, since, on the "Date" task, the visual interface was as good as the textual, and in the second session, the visual interface was better for the "Date" task.

Thus one goal for the next iteration of the TaskView interface is to redesign it to achieve at least the level of efficiency for the "Header" task currently shown in a typical inbox interface. One simple modification that may contribute to achieving this goal is to display sender and subject information in two separate columns in the TaskView interface. This would avoid users having to switch between displaying sender versus subject information. Such a design modification may be expected to allow performance at the level of the textual interface for "Header" tasks and the TaskView interface for the "Date" tasks.

5.5.2 Cognitive Abilities

Overall, high levels of each cognitive ability as measured in the study had a beneficial effect on performance time. The pattern of these effects suggests that cognitive abilities affect different aspects of human-machine interaction. Working memory (WM) was found to affect learning (first session), visual memory to affect task performance (second session - after task learning), while flexibility of closure (FC) affected performance during and after learning (main effect of FC on "Date" task performance in the first and second session).

The two user interfaces used in this study put different demands on different people. Users with low flexibility of closure performed overall slower in the Outlook Inbox condition (confirming the *Flexibility Of Closure Hypothesis*, which expected participants low on FC to perform worse in Outlook Inbox than in TaskView). In particular, their performance on the "Date" task was especially affected by the Outlook Inbox condition, while it was not affected at all by TaskView condition. A possible explanation is that embedding messages (and the date information in particular) in the textual inbox, among other messages, may require more discrimination, which likely creates a disadvantage for people with low flexibility of closure.

Participants with low visual memory performed worse for the "Header" task than for the "Date" task in both interfaces (not confirming the *Visual Memory Hypothesis*, which expected an interaction with the levels of user interface, such that participants low on VM would perform worse in TaskView than in Outlook). Task "H" required users to open and switch between more views (e.g., switching to display sender or subject information) and open more windows than in task "D". The switching caused changes in the visual field which might have been difficult to cope with for people low on visual memory. Those people may perform better if more visual constancy is maintained (e.g., Woods, 1984).

The *Working Memory Hypothesis,* which expected participants with high working memory to perform better than those low on WM in Outlook (but with no such differences expected to occur for the TaskView interface), was not confirmed. People with low working memory (WM) had a greater disadvantage on the "Header" task. The disadvantage was clearly visible in the TaskView interface, where performance of people with high WM was not affected at all. However, this significant difference appeared only in the first session. Thus it may be attributable to the effect of heaving to learn both the new interface and a new task. The additional load imposed on working memory by the need to hold more information when switching between different views (switching to display sender or subject information) did not significantly impact performance, since it did not appear in the second session. However, as discussed above, it did impact people low on visual memory.

5.6 Conclusions From the Study

This study showed the role of individual differences in interacting with two email user interfaces (Outlook and TaskView) that employed two distinctive representations of pending tasks in messages (standard textual representation and more visual representation). Users performed better on the "Date" task in the TaskView interface than they did in the Outlook Inbox interface, while on the "Header" task they performed better on the

Outlook interface than they did on the TaskView interface. This interaction between tasks and interfaces was independent of the three cognitive capabilities that I examined. However, there were significant interactions between the cognitive capabilities and the main effects of user interface and task. These interactions identify the combinations of user interface and task, where users low on respective cognitive abilities were adversely affected.

These results highlight the importance of considering alternative interfaces for different population groups and for different tasks that would accommodate individual differences in ability. The next chapter describes a further study using a redesigned email interface along with the rationale behind the interface modifications. The details of the new interface (WebTaskMail) are described in Chapter 4.

Chapter 6

WebTaskMail - User Study #2

Experiment!
Make it your motto day and night.
Experiment,
And it will lead you to the light.

Cole Porter, "Experiment" from "Nymph Errant"

6.1 Introduction

The previous chapter presented User Study #1, which compared a time-based representation of messages/pending tasks in the more visual email interface (called TaskView) with a more standard user interface (the Microsoft Outlook inbox) with respect to efficiency and effectiveness of information finding in email messages. Pending task dates were found more quickly using the more visual interface (TaskView), whereas other pending task attributes, that required information retrieval from message header or content, were found more quickly using the more standard text-based user interface. The study also showed that differences in cognitive abilities affect performance in processing email, and that particular combinations of tasks and interfaces lead to disadvantages for people with low levels of different cognitive abilities.

The purpose of the second study was to extend the previous findings by 1) using a user interface that is a design iteration of a TaskView interface informed by the previous study; 2) minimize undesirable differences between the textual and visual interface conditions; 3) logging user interaction with the email program to better understand user behaviour; 4) revising the independent measures employed in the study; 5) making the experimental procedure more robust.

1. User interface design iteration

In the previous study, the visual interface was found to be slower on the "Header" task than the textual interface. The current redesign aimed to make this difference in performance smaller, so that performance on task "Header" would no longer be worse in the visual interface. The resulting WebTaskMail interface includes in each view more information from the message header and thus requires less switching between different views. The new interface combines the timeline/calendar view of pending tasks with the sender and subject line information provided in the standard user interface. The two dimensional display of pending task information were designed to make information finding easier. This was achieved by a adding vertical "cursor" to help read dates, and by color coding the pending task's starting date in the message row background. A full presentation of the new interface is found in Chapter 4.

2. Different implementation of the "baseline" textual user interface

To minimize undesirable differences between the textual and visual interface, the textual interface was implemented as a modified version of the WebTaskMail interface. A description of the textual interface can be found in Section 6.3.2.

3. More extensive information collection during the experimental sessions

The previous study used only two behavioural measures: time to task completion, and accuracy. To gain insights into user interaction with the email program, additional behavioural information was collected. Two types of user interactions with the email programs (inbox sorting and scrolling) were logged into a database, along with time-stamps. Sorting changed the order in which messages were displayed in the inbox. Three types of sorting were possible: 1) by message's sender or subject; 2) by task field; 3) by date (start- or end-date). Scrolling was defined as the total amount of up and down scrolling (screen distance in pixels) of the inbox content performed by the study participant while working on a particular question.

4. Added independent measures

An additional cognitive ability was tested for - *speed of closure*. Speed of closure provides a complementary measure to the previously used flexibility of closure. While flexibility of closure measures the ability to extract piece of visual information from a distracting pattern, speed of closure measures the ability to recreate a whole shape from several pieces. The speed of closure test is based on *Street Gestalt*[1] *Completion Test* (Ekstrom, 1976).

1. Gestalt ***n***.- A perceptual configuration or structure that possesses qualities transcending the sum of its constituent elements or parts and that cannot be described simply in terms of its parts. (Colman, 2001)

5. Improvements to the experimental procedure

Questions used in the study were revised. Those found to be the most difficult[1] for participants of the previous study were removed or reworded. From the original set of 43 questions, 36 were left (see Section F.1 in Appendix F). The procedure of random drawing of questions was improved. In the previous study, a set of 21 questions was randomly drawn from the set of all questions in each experimental session. In this study, two separate sets of 18 questions each were randomly drawn by using a random number generator[2]. One third of the questions was reworded in such a way as to ask participants to look up dates based on information in the message headers, or vice versa. These questions were the basis of creating a new type of task: "Mixed". Since questions of this kind referred both to dates and headers, they were expected to involve mixed user strategies.

6.2 Research Questions and Expectations

The study was motivated by the three research questions addressed in the previous study. The first question was concerned with evaluating the impact of the designs:

- What effects did the two email interface designs used (text and visual) and the different types of task have on performance?

The second question was concerned with the impact of cognitive abilities:

- How is performance on different interfaces and tasks affected by different levels of cognitive abilities?

The third group of questions assessed the impact that strategies and experience had on performance in the tasks:

1. Based on the number of inaccurate answers, length of time taken to answer a question and on participants' observation.
2. As implemented in PHP 4.3.

- Can subjects be grouped by their performance and strategies (experimentally observed, objective measures) and if so, can such grouping be related to differences in cognitive abilities between people? Can it be related to other individual differences?
- Can subjects be grouped by their email handling style (self-reported, subjective measures, similarly as in Chapter 3 - Field Study). If so, can such grouping be related to differences in cognitive abilities between people?

6.3 Study Design

6.3.1 Method

As in the User Study #1 (Chapter 5), a mixed factorial design was used with user interface as an independent within subject factor (2 levels: Text and Visual). The study was conducted in two sessions lasting between 1.5 to 2 hours. Each subject used a different interface in each session. The design was balanced with respect to the order of interface use. There were also independent, between subject factors, based on four measured cognitive abilities (flexibility of closure, speed of closure, working memory, and visual memory). Scores for each of the cognitive abilities in the experimental sample were split at the median into two groups (high vs. low, levels of the ability). For each of the four cognitive abilities, these two levels of the ability (high vs. low) were defined as a pseudo-factor for the purpose of subsequent analyses of the experimental data. The factor Task was defined based on the type of target information that was required to answer questions. As discussed in Section 5.1.1, the Task factor had three levels: “Header” (H), “Date” (D), and “Mixed” (M). The new type “Mixed” was added in this study.

6.3.2 Apparatus

For the purpose of the study two limited feature set versions of the WebTaskMail interface were created (UI-Text and UI-Visual). In the UI-Text (Figure 6.2) temporal attributes of pending tasks were presented as text, while in the UI-Visual (Figure 6.1) temporal attributes of pending tasks were represented graphically.

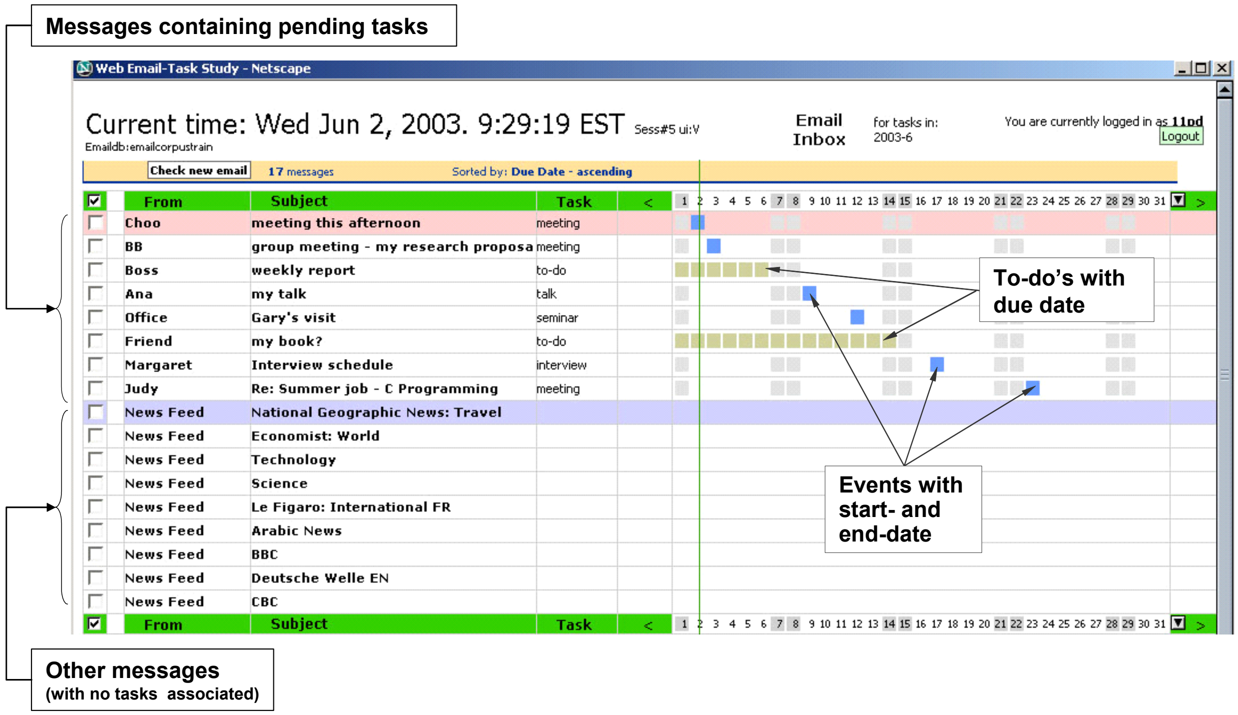


Figure 6.1. WebTaskMail—Visual UI.

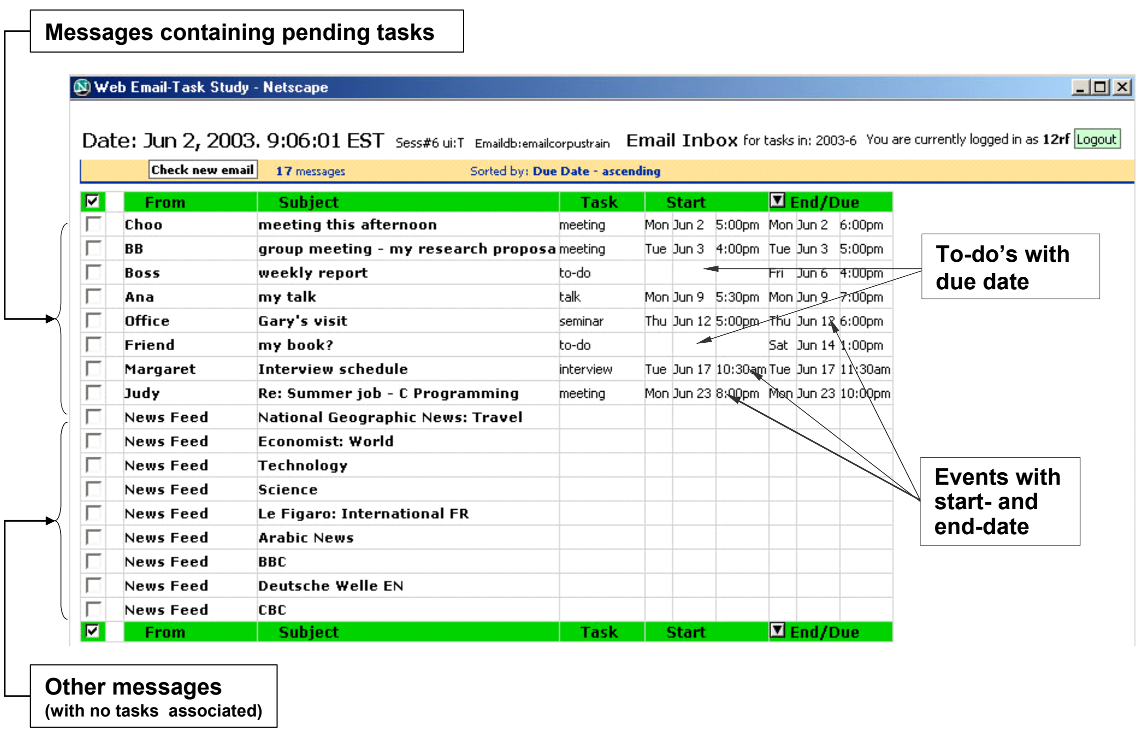


Figure 6.2. WebTaskMail—Text UI.

The programs were installed on a desktop PC equipped with a 17” CRT monitor.

Most forms of interaction with the interface (message viewing, inbox sorting, scrolling, and answers to questions) were logged into a relational database. All sessions were also recorded using the Camtasia software for capturing computer screen (along with sound). Email inboxes in each session contained the same 54 messages, of those 44 had associated pending tasks with them, while 10 had not. The corpus of 44 email messages were the same as used in the previous study (Chapter 5).

6.3.3 Participants

Twenty four people participated in the experiment. Nineteen participants were university students (4 undergraduate, 10 Master and 11 Ph.D. students from engineering and science departments), and 5 participants were full-time employees from outside companies. There were 9 females and 15 males. Participants were screened for at least moderate use of email. On the average, participants had used email for seven and a half years. All participants were paid $25 for their time ($10 per hour), while half of the participants received an additional bonus of $10 based on their performance in the study.

6.3.4 Procedure

The two sessions were conducted in the experimenter's office and spread at least one day apart (1 to 7 days). Each session consisted of the study protocol explanation, the user interface training (10 to 15 minutes), and the main task (15 to 25 minutes). The main task was to find information about pending tasks in email messages. Information finding was driven by multiple-choice questions displayed on screen, along with choices. A set of different 18 questions was drawn randomly in each session from a larger set of 36 questions. Two cognitive tests were administered at the beginning, and one at the end of each session. (Different tests were administered in each session.) After the main task, participants were debriefed and asked to fill out a subjective evaluation questionnaire. In the second session, that questionnaire was followed by a subjective questionnaire asking participants to compare the two WebTaskMail interfaces which they used in the study. The first subjective questionnaires contained 11 and the second 8 statements about the interfaces (see Section F.4 in Appendix F). The study participants rated their agreement with those statements on a 5-point Likert scale (strongly disagree, disagree, neutral, agree, strongly agree). Participants also filled out, at their leisure, a web survey containing demographic and email use questions (see Section F.2 in Appendix F).

6.3.5 Measures

Experimentally controlled measures:

1. Two levels of user interface: UI Text and UI Visual;
2. Three tasks: *Header* - “H”, *Date* - “D”, and *Mixed* - “M”.

Original independent, between subject measures:

1. Cognitive abilities were measured using the Factor-Referenced Kit of Tests (Ekstrom, 1976). Flexibility of closure was assessed using CF-2; speed of closure was assessed using CS-1; two visual memory tests were administered: 1) visual memory for shapes was assessed using MV-1; 2) visual memory for 2D maps was assessed using MV-2. Working memory was measured using the auditory digit span test (MS1). The range of scores for the study population is shown in Table 6.1.
2. Demographic and email use data collected in a web survey.

Statistic	Cognitive ability				
	CF-2[a]	CS-1[a]	MV-1[a]	MV-2[a]	WM
Mean	58.4%	46.7%	51.8%	59.3%	6.74
Std. dev.	14.8%	25.0%	23.4%	31.7%	1.11
Min value	33.8%	0.0%	12.5%	0.0%	5.5
Max value	88.0%	82.5%	87.5%	100%	10.0
Number “Low”[b]	12	12	10	8	10
Number “High”[b]	12	12	14	16	14

Table 6.1. Range of cognitive abilities for the study sample[c].

a. These test results are reported as percentage scores.

b. Number “Low” & “High” are the numbers of people in the study sample who were, respectively, below or above (or equal) to the median value of each cognitive ability.

c. Statistics for other populations provided by the Cognitive Test authors are shown in Appendix B.

Derived independent, between subject measures (treated as pseudo factors):

From the Factor-Referenced Kit of Tests:

1. FC- scores on CF-2 grouped into two levels by median (low-high)
2. SC - scores on CS-1 grouped into two levels by median (low-high)
3. VM1 - scores on MV-1 grouped into two levels by median (low-high)
4. VM2 - scores on MV-2 grouped into two levels by median (low-high)
5. WM - scores on MS-1[1] grouped into two levels by median (low-high)

Dependent, within subjects measures:

1. Efficiency, as measured by the time participants taken to answer questions;
2. Effectiveness, as measured by ability to find the correct information (answer);
3. User interaction with the interface: sorting inbox by different columns (From, Subject, Task, Start-date, End-date), scrolling inbox, and opening messages.)
4. Subjective evaluation of both interfaces.

6.4 Results Overview

An overview of the most important results is presented first. The following section describes the results in more detail, along with analyses that led to them.

Assessing the impact of the modified email user interface is one of the main concerns of this thesis. This concern arises because the visual WebTaskMail interface embodies the claim about the visual representation of pending task information being better than the textual presentation with respect to the user performance. The study sought to find the effects of the two email interface designs (text and visual) on performance. A secondary goal was to examine the influence of different types of task on performance, both across the interfaces as well as in each interface separately. The effects were examined by conducting a series of analysis of variance.

1. The scoring used on MS-1 differed from the originally suggested by the reference kit authors. A different scoring scheme was used to obtain scores reflecting directly the working memory span.

The difference in performance between the two interfaces was smaller than in the previous study. There was a significant difference in performance time between the user interfaces, but only in the first study session. Consequently, dependent measures (performance time and logged user interactions - scrolling and sorting) were checked for a possible order effect.

6.4.1 Order and Learning Effects

A significant order effect of experimental session on performance time was found. Participants who used the visual interface in the first session performed the tasks significantly slower (33s, that is 3 to 7s slower than in the other three combinations of UI and UI order - Table 6.2).

	1st Session	2nd Session
UI Text	30s	28s
UI Visual	**33s**	26s

Table 6.2. Order effect of experimental sessions (UI) on performance time (seconds).

After finding the order effect, I examined whether this effect could be attributed to learning[1]. A learning effect was defined as a decreased performance time (i.e., improved performance) during the course of a person's participation in the experiment. A learning effect was indicated by a significant correlation between trial number (i.e., question number) and performance time, indicating that the slope of the learning curve (as fitted by regression to the log-transformed data) was non-zero.

The largest learning effect was observed for UI-Visual in the first session. Participants high on working memory (WM) performed faster than participants low on WM (right side of Figure 6.13). However, learning occurred for both groups at approximately the same rate and thus low-WM participants had not reached the same level of performance by the end of the first session. For UI-Text, in the first session (left side of Figure 6.13),

1. The main user tasks was in both sessions preceded by a set of training task, which were approximately 1/3 length of the main tasks.

people low on WM were initially slower. However, they reached roughly the same performance level at around the seventh question. The larger difference in performance between participants who were low and high on WM in the visual interface than in the textual interface suggests that the low-WM participants were affected not only by learning the task, but also by learning the new visual interface. In the second session, learning in the UI-Text condition was not observed. In contrast, learning continued in the UI-Visual condition.

To separate the potentially confounding order effect and possible asymmetric transfer effects between the interfaces, the following analyses report the results from the first and the second session[1] separately.

6.4.2 Impact of the Interface Design and Tasks

6.4.2.1 User Interface and Task

The visual interface was slower in the first session by 3 seconds, or about 10%, than the textual interface. This slower performance appeared to be mostly due to learning of the tasks and the visual interface. The performance was particularly slow on the "Mixed" task (M). There was no difference in performance time between the two interface conditions in the second session (Figure 6.5).

In the first session, performance time on task "Mixed" varied highly between the participants[2] in both interface conditions. In the first session, task "Mixed" was the slowest on the visual interface, while in the second session task "Mixed" was performed at a level much more similar to the other tasks. In the second session, there was a significant interaction between the user interface and the task. The "Date" task (D) was the fastest in the

1. In the separate analyses of session data that were carried out, user interface becomes a between-subject factor.
2. Due to the high variability of performance on task M in UI Visual and UI Text, no significant interaction or main effects involving task were found in the first session.

visual interface (21s), while task “Mixed” was the fastest in the text interface (20s). The “Header” task (H) was the slowest in the text interface (30s). Performance on tasks “Header” and “Mixed” (27s and 28s) was in the visual interface at about the same level as performance on task “Date” in the textual interface (26s) (Figure 6.3).

Performance in the second session was overall faster (by 4s to 5s per question), and there was also generally less user interaction in that session (less scrolling and less sorting, with one exception—there was more sorting on task “Mixed”). In particular, participants scrolled the least in the second session on the text interface and they scrolled the least on task “Mixed” (Figure 6.6).

Participants sorted the most in the first session on the textual interface, while they sorted the least in the first session on the visual interface, and about the same in the second session on both interfaces. They sorted more on task “Header” than on task “Date” or “Mixed” (Figure 6.7). The effect of the task level on sorting by individual columns (Figure 6.9) demonstrated that participants sorted according to the information type of the search target.

The observed differences in performance on tasks were due to the differences in interface design as well as to the differences in tasks.

6.4.2.2 Subjective Evaluation

Numerous studies in human-computer interaction demonstrated that objective performance measures do not necessarily agree with the users’ subjective preferences and their perception of performance (Dillon et al. 1999; Modjeska & Chignell, 2001). Differences in performance (or their absence) observed in this study were not reflected in subjective evaluations. Although participants were slower on the visual interface in the first session, and did not show differences in performance time in the second session, they expressed belief that their overall performance was better using the visual interface and were neutral about which interface was easier to learn.

Participants agreed that the visual interface was easier to use than the textual interface, and expressed their preference for using the visual UI to handle and view to-do's and events. The visual interface was strongly preferred to the textual interface for providing an overview of all pending tasks. Thus, providing at-a-glance overview of tasks in the visual design was successful, at least in terms of its subjective evaluation after participants used the interface in the course of the study.

6.4.3 Impact of Cognitive Abilities

Independently of evaluating the impact of the UI design, the study was concerned with the impact of cognitive abilities. The guiding questions here are: How is performance on different interfaces and tasks affected by different levels of cognitive abilities? Is the impact of cognitive abilities different across the two experimental sessions?

6.4.3.1 Interaction and Main Effects of Cognitive Abilities

An interaction effect of working memory (WM) with UI was found. This effect was observed only in the first session. Learning on the visual interface was slowed down by the low level of working memory (on average, performance time for the low-WM was 41s, 10-15s slower than in the other conditions). There were no differences in performance time on the two interfaces for people with different levels of WM *after* the first "learning" session. However, the overall performance time (across both interfaces and all tasks) was adversely impacted by the low level of WM in both sessions. The total number of inbox sorting actions was affected by WM in a similar way, with people low on WM performing more sorting than people high on WM.

Interaction of visual memory for shapes (VM1) with user interface was found to impact the amount of scrolling performed by participants in the second session. Participants who were high on VM1 scrolled more in the visual interface, while there was no difference in scrolling between the two interfaces for participants low on VM1.

WM and VM1 were the only two cognitive abilities that were found to interact with level of user interface. Their interaction, however, differed in two ways. WM affected performance time, whereas VM1 affected the amount of scrolling. The VM1*UI interaction effect on scrolling in the second session can be said to had been influenced by the differences in the visual representations, while the WM*UI interaction effect on time in the first session suggests that the differences in the visual representations affected learning of tasks and the visual interface.

An interaction effect on performance time of flexibility of closure (FC) with task was found in the second session. While performance of the low- and high-FC people did not differ for tasks "Header" and "Date", for task "Mixed" people low on FC were significantly slower than those high on FC (an average of 27 seconds per question vs. 21 seconds). Task "Mixed" required users first to find and remember one type of information (e.g., a date), and then to relate it to other type of information (e.g., person's name). Performance of people at different levels of FC was affected by this integration of different information types and not by the differences in information representation. Apparently, this task imposed more demands on cognitive processes related to the flexibility of closure. FC was the only cognitive ability found to interact with task.

No interaction effects were found for visual memory for 2D positions (VM2). However, a main effect of VM2 on the total number of inbox sorting actions was observed in both sessions. People low on VM2 sorted less, while people high on VM2 sorted more. This was in contrast to the described earlier main effect of WM on sorting, where the directions was opposite, with people low on WM scrolling more.

No significant effects were found for speed of closure (CS1). Table 6.3 and Table 6.4 summarize the effects of cognitive abilities.

Cognitive Ability	Significant Differences
	Both Sessions
VM2	low VM2 - sort less, high VM2 - sort more
WM	low WM - sort more, high WM - sort less
WM	low WM - slower, high WM - faster

Table 6.3. Summary of cognitive ability effects—main effects across both sessions.

Cognitive Ability	Significant Differences	
	1st Session	2nd Session
FC		high CF - faster on Task “Mixed”
VM1		high VM1 - scroll more in UI Visual than Text (no difference for low VM1)
WM	low WM - slow in UI Visual	

Table 6.4. Summary of cognitive ability effects—interactions specific to each session.

6.4.3.2 Dynamic Role of Cognitive Abilities

Although order effects are not desired in a typical study evaluating user interface, these effects enabled me to find dynamic aspects of cognitive abilities. Different cognitive processes, and thus abilities, play a role at different *stages* of human-computer interaction. An interaction effect of working memory (WM) and interface on performance time appeared only in the first session, while there was also a main effect of working memory on performance time in both sessions. This suggests the primary role of working memory in task and interface learning, in addition to overall impact of WM on performance. Interaction effects of flexibility of closure (FC) and visual memory (VM1 - shapes) appeared only in the second session, after most learning already took place. Main effects of working memory (WM) and visual memory (VM2 - 2D locations) were observed in both sessions. The effects for each of these two cognitive abilities had the same character and direction in both sessions. Thus, some cognitive abilities contribute a dynamically changing, variable component to the effects on performance, while others a constant component. Working memory contributed in both ways.

6.4.4 Participants Clusters

Individual variables such as cognitive abilities and demographic variables provide one type of potential groupings of subjects. Another method of grouping subjects is to use cluster analysis, based on behavioural measures, for example, on time taken, amount of scrolling, on email reading and keeping behaviour (Section 3.3.4, Chapter 3) etc. as the dependent measures, and subjects as the observations to be clustered. Two cluster analyses were performed. First, based on the observed measures: performance time, amount of scrolling and sorting for each task. Second, based on the self-reported email behaviour related to handling prospective information in email. A common question asked in both cases was whether the differences between participant groupings created in cluster analyses can be attributed to differences in cognitive abilities between people.

6.4.4.1 Performance and Effort Clusters

A two-cluster solution was selected based on performance time, amount of scrolling and sorting for each task. The first cluster contained 8, while the second contained 16 people. People in cluster 1 took more time to answer the questions, and they used more scrolling and more sorting. People in cluster 2 were faster and did less scrolling and sorting. One plausible interpretation of these results is that people in cluster 1 expended more effort in performing the tasks. The clusters obtained in this analysis will be called "Performance & Effort Clusters" or PE-Clusters. Next it was examined whether the values of demographic variables, email experience and cognitive abilities differed between the two clusters. Statistical differences were found for speed of closure (CS1), visual memory (shape-VM1 and 2D-position-VM2), working memory (WM) and for email experience (Table 6.5). These results suggest that the systematic differences between participants, in terms of how they carried out the tasks, may be attributable (at least in part) to differences in cognitive abilities and experience in handling email.

Cognitive abilities and other ind. differences	Significant Differences	
	PE-Cluster 1 - slow, more effort	**PE-Cluster 2 - fast, less effort**
SC1	low	high
WM	low	high
VM1	high	low
VM2	high	low
Email Experience	low experience	high experience

Table 6.5. Performance clusters.

6.4.4.2 Email Handling Style Clusters

The second cluster analysis was performed in order to examine if the behavioural differences between people described earlier as “email handling styles” (Section 3.3.1 in Chapter 3), with two distinct styles 1) keep prospective information in email; 2) transfer prospective information from email, could be attributed to differences in demographic measures, cognitive abilities or email experience. A two-cluster solution was selected. The first cluster contained 7, while the second 16 people[1]. The clusters obtained in this analysis will be called “Email Style Clusters” or ES-Clusters. People in ES-Cluster 1 seem to have more control over their email behaviour, by not letting incoming emails interrupt other activities and by setting specific times to read email, they tend not to use email to handle prospective messages. In contrast, people in ES-Cluster 2 treat email as a *habitat*, letting incoming messages interrupt other activities and reading messages continually. They also tend to use email to keep and handle prospective messages.

Next it was examined whether the values of demographic variables, email experience and cognitive abilities varied between the two clusters. Significant differences were found for flexibility of closure (FC) and for email experience. People in ES-Cluster 2 tended to have more email experience and were high on FC (Table 6.6).

1. Email survey data was partially missing for one of the 24 participants, thus N=23.

Cognitive abilities and other individual differences	Significant Differences	
	Email Cluster 1 - transfer prospective email	Email Cluster 2 - keep prospective email
FC	low	high
Email Experience	low experience	high experience

Table 6.6. Email style clusters.

Extracting information from the variety of email messages may be more demanding on people low on FC. Therefore, the low-FC users do not keep those different kinds of information in one place (in email), but rather transfer information to different applications designed to handle specific information types (e.g., they transfer meeting and appointment information to a day timer). Two plausible explanations were identified for why people with more email experience were found in ES-Cluster 2. Those using email for a longer time may be receiving more email messages and at the same time a wider variety of messages types. Thus, there is a higher probability that they read email more often and receive and keep prospective information in email.

6.5 Detailed Presentation of Results

6.5.1 Order Effect

There was a significant effect of order of experimental session. ($F(1,39)=10.9$, $p=.003$, $\eta^2 =.331$). Participants who used the visual interface first performed the tasks slower (33s per task on average, 3 to 7s slower than in the other three combinations of interface and order Table 6.7 and Figure 6.5). To disentangle the potentially confounding order effect and possible asymmetric transfer effects between the interfaces, the following analyses report the results from the first and the second session[1] separately.

1. In the separate analyses of session data that were carried out, user interface becomes a between-subject factor.

	1st Session	2nd Session
UI Text	30	28
UI Visual	33	26

Table 6.7. Order effect of experimental sessions (UI) on performance time (seconds).

The subsequent analyses of the results were structured by the research questions described in earlier.

6.5.2 Effects of User Interface Design

6.5.2.1 Performance Time and Accuracy

The first research question was addressed by examining the interaction between task and user interface. The effect of this interaction on time as the dependent measure was only significant in the second session (Session 2: $F(2,40)=6.32$, $p=.004$, $\eta^2=.24$). In the first session, performance on the "Mixed" task varied highly between participants (therefore no significant differences, $F(2,40)=1.7$, $p>.2$). Task "M" was the slowest in the first session on the visual interface, while in the second session task "M" was performed at about the same level as other tasks. In the second session, task "Date" was the fastest in the visual interface (21s), while task "Mixed" was the fastest in the text interface (20s) (Figure 6.3).

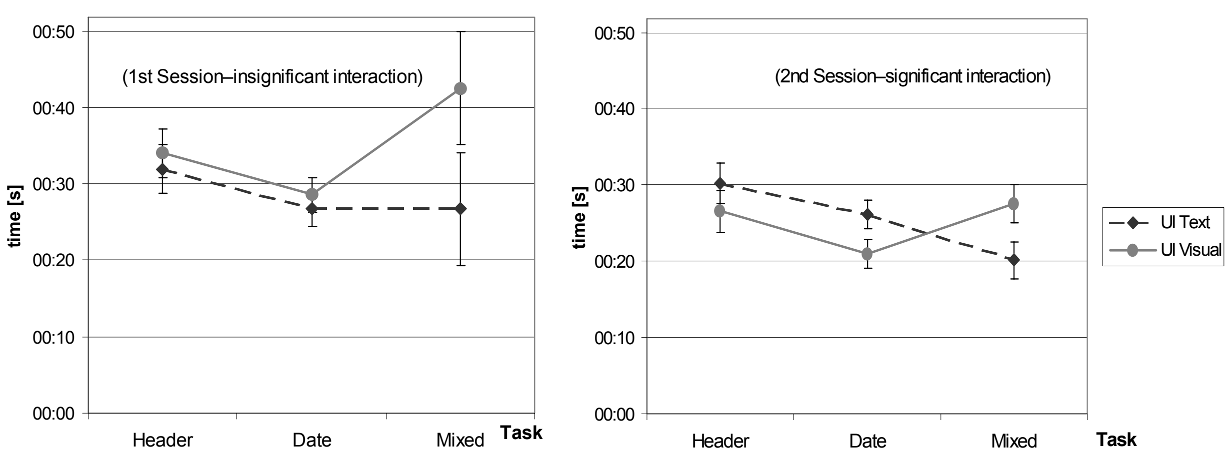


Figure 6.3. Effects of interaction UI*Task on time in the both sessions.

There was also a main effect of task in the second session. ($F(2,40)=3.9$, $p=.03$, $\eta^2=.163$). The second session was overall faster (by 4s-5s). However, for task "Mixed" the average performance between the sessions improved by 11s from 35s to 24s. (Figure 6.4).

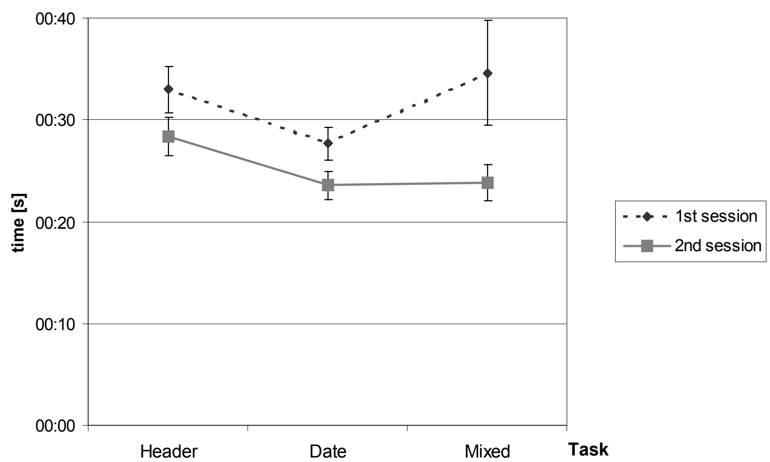


Figure 6.4. Effect of Task on performance time in both sessions.

There was a significant effect of user interface on performance time in the first session (as described in the order effect). The slowest performance was on the visual interface in the first session (33s on the visual vs. 30s on the text interface). In the second session, the was no significant difference (F~1, p>.1) in performance times between UI Text and UI Visual (28s and 26s respectively). (Figure 6.5)

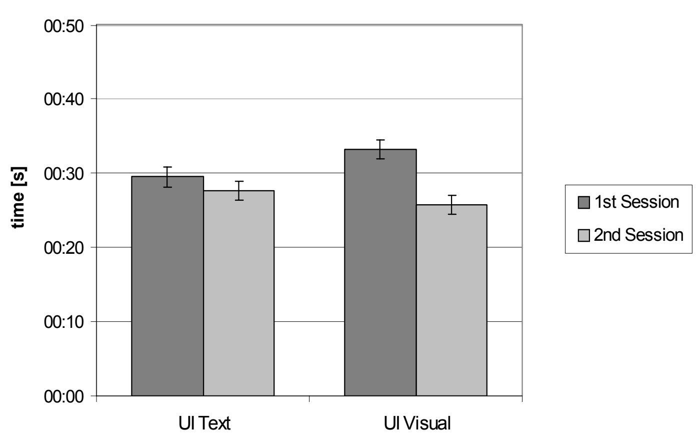


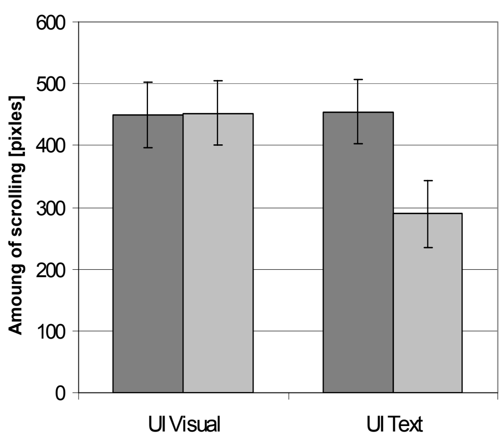
Figure 6.5. Main effect of UI on performance time in both sessions.

The significant interaction between UI and Task, and main effects of UI and Task, suggest that participants' performance was especially influenced by the visual interface and task “M” in the first session. In this study condition, participants performed slower because they took more time to learn the task and the interface. Section 6.5.3.1.3 will discuss learning in both sessions in more detail.

For accuracy, there was no interaction between user interface and task (F<1). However, there was a main effect of task in the second session ($F(2,40)=3.39$, $p=.045$, $\eta^2=.145$). Task “H” questions were performed more accurately (98% accuracy) than were task “D” (90%) and task “M” (89%) questions. There was no significant difference between accuracy in the first and in the second sessions. The overall average accuracy was 94%.

6.5.2.2 Scrolling and Sorting

A series of analyses of variance were conducted to determine whether or not experimental conditions (UI and Task) affected the amount of scrolling and sorting that was used in the experiment. There was a user interface main effect on the amount of scrolling in the second session (Session 2: $F(1,20)=4.77$, $p=.041$, $\eta^2=.193$). Users scrolled the least in the second session in the text interface (an average of 290 pixels per question vs. about 450 pixels in all other conditions). A task main effect was observed in both sessions (in session 1: $F(2,40)=5.55$, $p=.007$, $\eta^2=.217$; in session 2: $F(2,40)=5.55$, $p=.007$, $\eta^2=.217$). Users scrolled considerably less in task “M” questions (an average across the two sessions of 211 pixels, versus 482 and 402 pixels for tasks “H” and “D” respectively) (Figure 6.6).



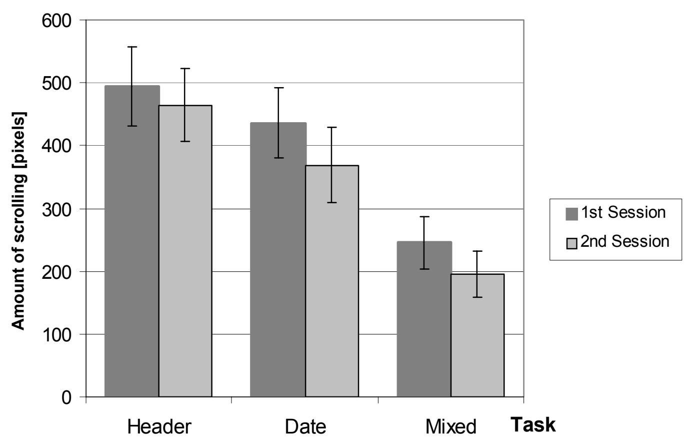


Figure 6.6. Main effects of UI and of Task on scrolling in both sessions.

There was a significant difference in sorting between the two user interfaces (Session 1: $F(1,20)=11.4$, $p=.003$, $\eta^2=.363$), with more sorting in text (.53 sorts per question, on average) than in the visual interface (.16). The amount of sorting performed in the second session was about the same in both interfaces (.37 vs. .39 sorts per question for the textual and visual interface respectively). (Figure 6.7).

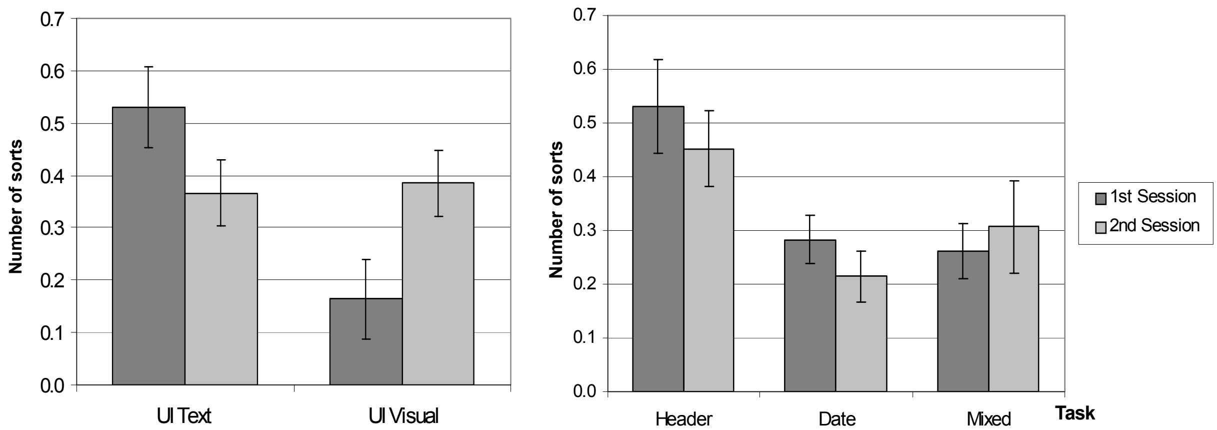


Figure 6.7. Main effects of UI and of Task on sorting in both sessions.

As shown in Figure 6.7, total amount of sorting decreased in the 2nd session for tasks D and H, but increased for Task M (from .26 to .31 per question). The Task effect was significant in each session (for 1st session: $F(2,39)=10.76$, $p<.001$, $\eta^2=.35$; for 2nd session $F(2,38)=5.72$, $p=.007$, $\eta^2=.22$).

There were significant user interface effects in the first session on sorting by each individual element (Figure 6.8), that is on sorting by From/Subject ($F(1,20)=4.42$, $p=.048$, $\eta^2=.181$), by the Task-column (Session 1: $F(1,20)=3.47$, $p=.077$ (borderline), $\eta^2=.148$), and by Date (Session 1: $F(1,20)=F(1,20)=6.36$, $p=.02$, $\eta^2=.24$).

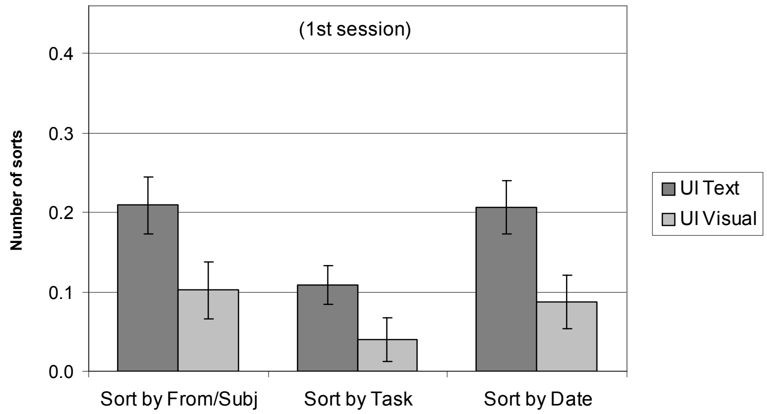


Figure 6.8. Effects of UI on sorting by individual inbox columns (first session).

There were also significant Task effects in both sessions on each individual type of sorting, that is on sorting by From/Subject (Session 1: $F(1.4,27)=30$, $p<.001$, $\eta^2=.6$; Session 2: $F(2,40)=30.5$ $p<.001$, $\eta^2=.604$), by the Task-column (Session 1: $F(2,40)=5.7$, $p=.007$, $\eta^2=.221$; Session 2: $F(2,40)=6.7$, $p=.003$, $\eta^2=.251$), and by Date (Session 1: $F(2,40)=15.2$; $p<.001$; $\eta^2=.432$; Session 2: $F(2,40)=7.1$, $p=.002$, $\eta^2=.262$) (Figure 6.9). These effects were to be expected, confirming that participants were sorting messages in the inbox depending on the Task, that is, depending on the kind of target information they were looking for. For task "H", they sorted mostly by the From/Subject columns; for task "D", mostly by the Date columns (Start- and End-Date); while for task "M", they sorted, with almost an equal frequency, by the From/Subject, by the Task, and by the Date columns.

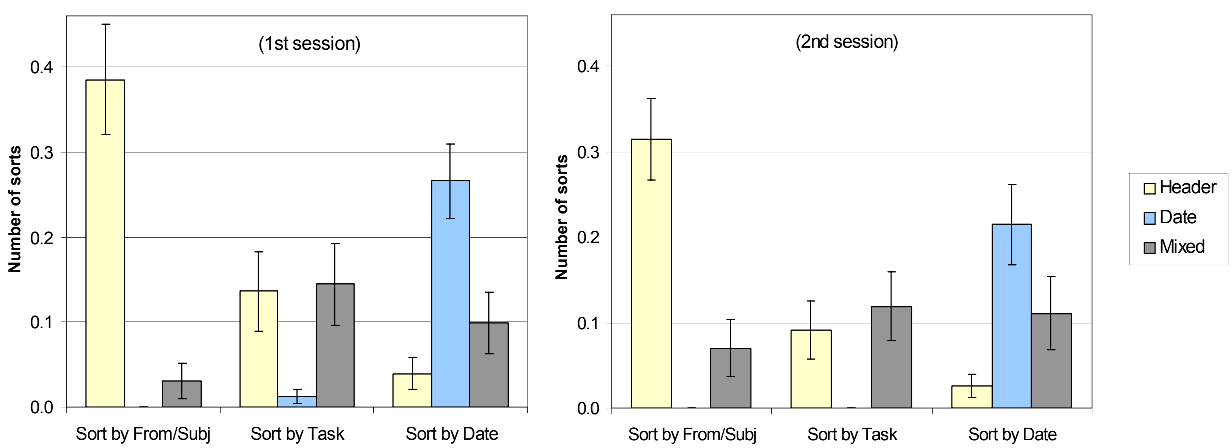


Figure 6.9. Effect of Task on sorting by individual elements in both sessions.
The total amount of sorting is broken down by the sort column and color-coded by the Task (see legend)

In summary, the visual interface was slower in the first session (by 3s or about 10% slower than UI Text). This lower performance appeared to be mostly due to slower responses to the task “M” questions. The second session was overall faster (by 4s to 5s per question). There was no significant difference in accuracy between the sessions and between the two interfaces. In the second session, task “H” was the slowest (28s vs. 24s for the other tasks). Participants scrolled less in the second session on the text interface, with the least amount of scrolling on task “M”. Overall, there was less scrolling performed in the second session. Participants sorted the most in the first session on the textual interface, while they sorted the least in the first session on the visual interface, and about the same in the second session on both interfaces. They sorted more on task “H” than on task “D” or “M”. One possible explanation for this result is, that once the participants learned the task (after the first session) the amount of sorting did not depend on the interface, but only on the task. The effect of the Task level on sorting by individual columns demonstrated that participants sorted according to the information type of the search target.

6.5.3 Effects of Cognitive Ability

The second of the three research questions was addressed by examining the effects of the three way interactions between type of interface, type of task, and each of the cognitive abilities[1] on performance time, scrolling and sorting. The abilities assessed included the two measures of visual memory (VM1, VM2) and the measures of working memory (WM), speed of closure (CS1), and flexibility of closure (CF1). None of the other three way interactions between UI, Task, and any of the cognitive abilities were significant. The two-way interactions and main effects are described in the following subsections.

1. In the repeated-measure analyses reported in this chapter the Hyun-Feldt criterion is quoted in those cases where it differs markedly from the p-value using sphericity assumptions. In such cases non-integer degrees of freedom are sometimes reported as a result.

6.5.3.1 Effects of Working Memory

6.5.3.1.1 Effects of WM on Performance Time

There was a significant interaction between UI and WM in the first session (Session 1: $F(1,20)=11.03$, $p=.003$, $\eta^2=.355$) with the slowest performance occurring for participants low on WM in the Visual interface condition (41s vs. 26s-31s in other study conditions), as shown in Figure 6.10.

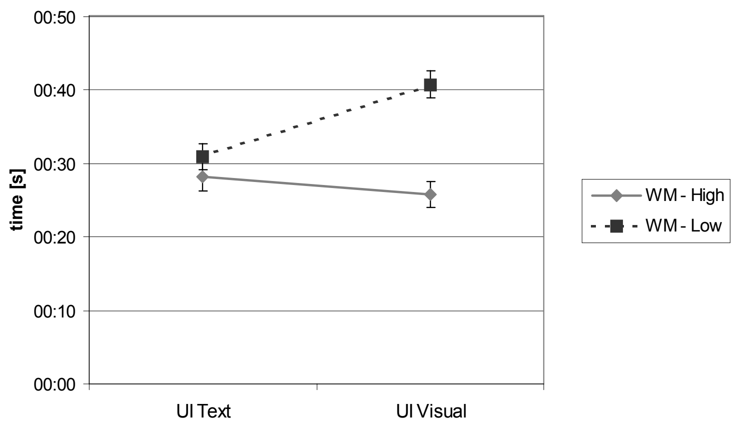


Figure 6.10. Effect of UI * WM on performance time (first session).

There was also a main effect of WM on performance time in both sessions (Session 1: $F(1,20)=22.98$, $p<.001$, $\eta^2=.535$; Session 2: $F(1,20)=10.77$, p.004, $\eta^2=.35$), with the low-WM participants performing slower than the high-WM (36s vs. 27s in session 1 and 30s vs. 24s in session 2). (Figure 6.11)

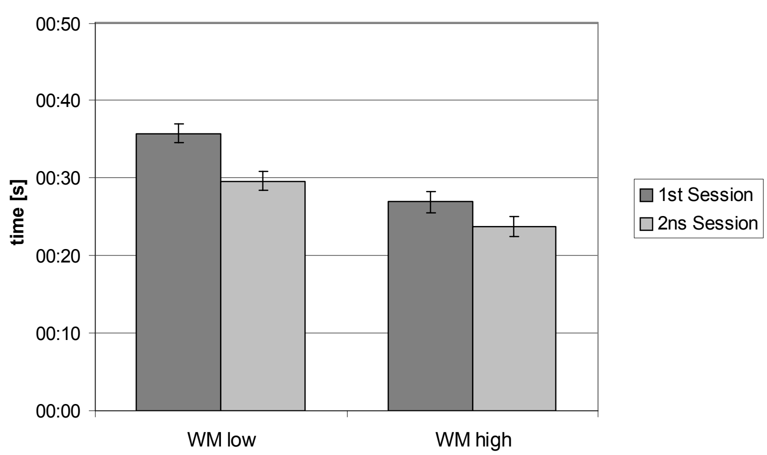


Figure 6.11. Main effect of WM on performance time (1st and 2nd session).

Similar effects on performance time were found for email experience, with a borderline interaction between user interface and email experience ($F(1,20)=4.07$, $p=.057$, $\eta^2=.169$). Participants with low email experience were the slowest when using the visual interface in the first session (40s vs. 27s-33s for the other three combinations of user interface and email experience). Overall, people with less email experience performed slower (36s vs. 27s) than people with more email experience ($F(1,20)=10.75$, $p=.004$, $\eta^2=.35$).

6.5.3.1.2 Effects of WM on Sorting and Scrolling

There was an effect of WM level on the total amount of sorting (Session 1—borderline: $F(1,20)=4.13$, $p=.056$, $\eta^2=.171$; Session 2, significant: $F(1,20)=6.45$, $p=.02$ $\eta^2=.244$). People with low WM tended to sort more frequently than those with high WM (Session 1: .45 vs. .25; Session 2: .43 vs. .19 sorts per question) (Figure 6.12).

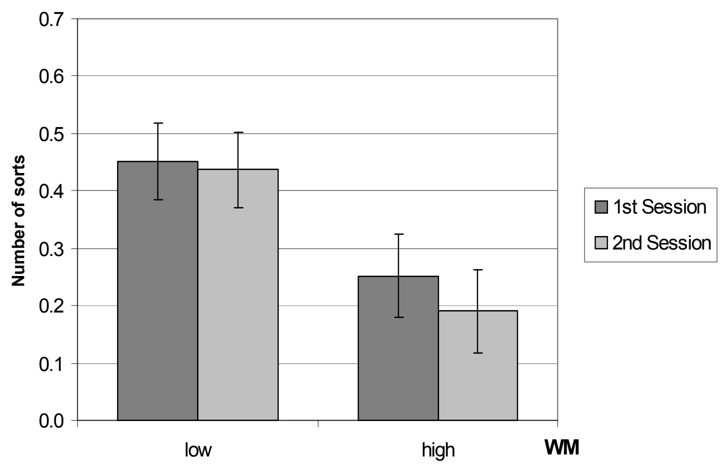


Figure 6.12. Main effect of WM on the total amount of sorting.

People with less email experience (544 pixels of scrolling per question, on average) scrolled significantly more ($F(1,20)=10.75$, $p=.004$, $\eta^2=.350$) than people with more experience (297 pixels per question). There was no corresponding effect for the low-WM people, who did not scroll significantly more than those with high WM.

6.5.3.1.3 Effects of WM on Learning (within sessions)

I examined if learning (as reflected in decreased performance time during the course of a person's participation in the experiment) took place within both sessions, and if it differed for high vs. low WM participants. A learning effect was indicated by a significant correlation, indicating that the slope of the learning curve (as fitted by regression to the log-transformed data) was non-zero.

The largest learning effect was observed for UI-Visual in the 1st session. Participants high on WM performed faster than participants low on WM (Figure 6.13 - right side). However, learning occurred for both groups at approximately the same rate (as reflected in the slope of the learning curve fitted to the data) and thus low-WM participants had not reached the same level of performance by the end of the first session.

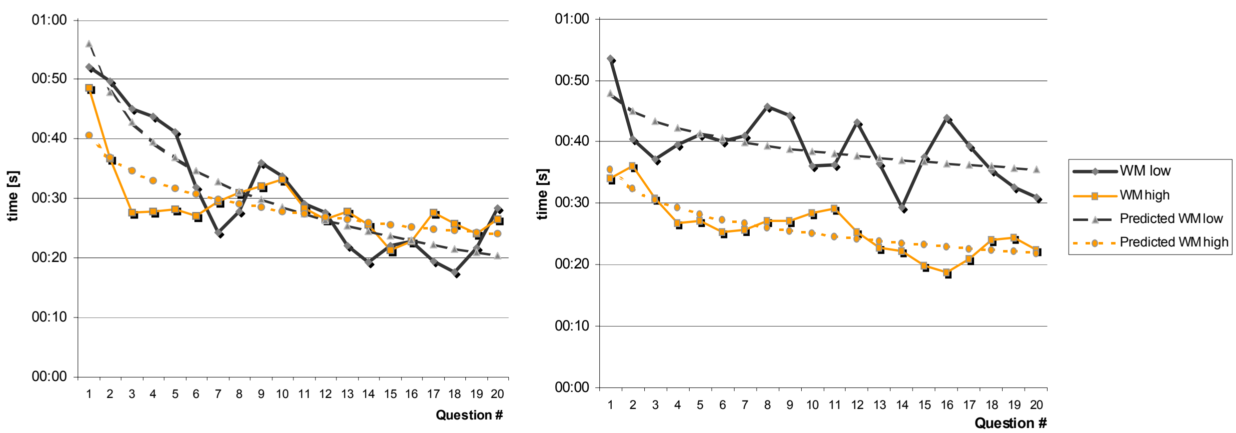


Figure 6.13. Learning in the 1st session in UI-Text & UI-Visual - effects of WM.
(smoothed data with predicted learning curves fitted by regression to the log-transformed data)

For UI-Text, in the first session (Figure 6.13 - left side), people low on WM were initially slower. However, they reached roughly the same performance level at around the seventh question. The larger difference in performance between participants who were low and high on WM in the visual interface than in the textual interface suggests that the low-WM participants were affected not only by learning the task, but also by learning the new visual interface.

In the second session, learning in the UI-Text condition was not observed. In contrast, learning continued in the UI-Visual condition. As can be seen from Figure 6.14, participants were overall faster than in the first session and stronger learning took place for participants low on WM.

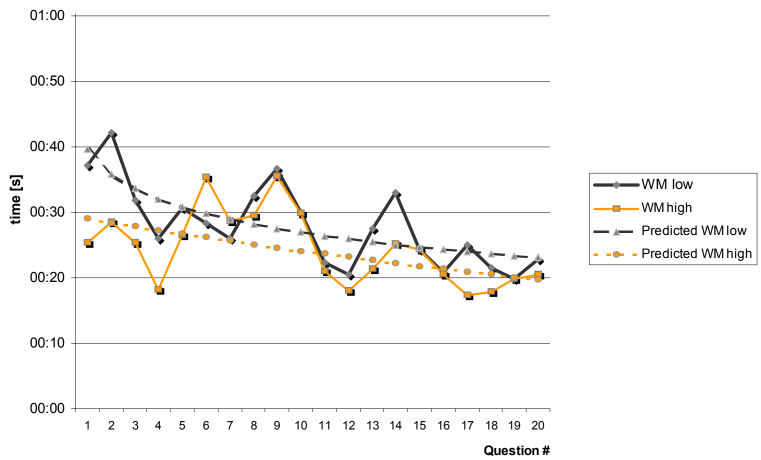


Figure 6.14. Learning in 2nd session in UI-Visual and two levels of WM.
(smoothed data with predicted learning curves fitted by regression to the log-transformed data)

In addition to effects of WM on learning, people high on WM continued to be faster in the 2nd session (Session 1: 36s & 27s and in 2nd session: 30s & 24s for low and high WM respectively) as illustrated in Figure 6.11.

The learning effects may indicate that participants adjusted their behaviour as they learned to use the visual interface. Some evidence for this was observed in an analysis of the results for the second session.

6.5.3.1.4 Analysis of Selected Questions

A detailed analysis was carried out on selected questions in order to gain insight into the observed effects. Questions were selected based on the following criteria: a) above average accuracy and completion rate; b) relative simplicity; c) 50% type D and 50% type M questions. Six questions were selected for detailed analysis. Three of them were of type "D" (questions 1, 9, and 14), and the remaining three were of type "M" (questions 7,8, and 25). For those questions, user actions recorded by a screen-cam were transcribed.

There were significant differences in performance time between the six selected questions (F(2.7,56)=5.71, p=.003, η^2=.214) (Figure 6.15) and there was a significant effect of WM levels on participant performance in these questions (F(1,21)=6.94, p=.016, η^2=.248). Follow up analyses were then carried out to establish for which of the selected questions performance time differed significantly. Question 7 ("When does the next seminar take place?") was found to be the only question with a significant difference in performance time between high and low WM participants (F(1,21)=5.57, p=.032, η^2=.271). Performance time was 36s for participants low WM and 23s for participants high on WM. (Figure 6.16).

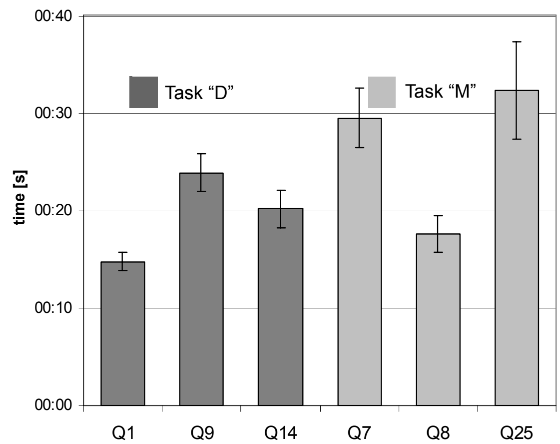


Figure 6.15. Performance times (seconds) for each selected question.

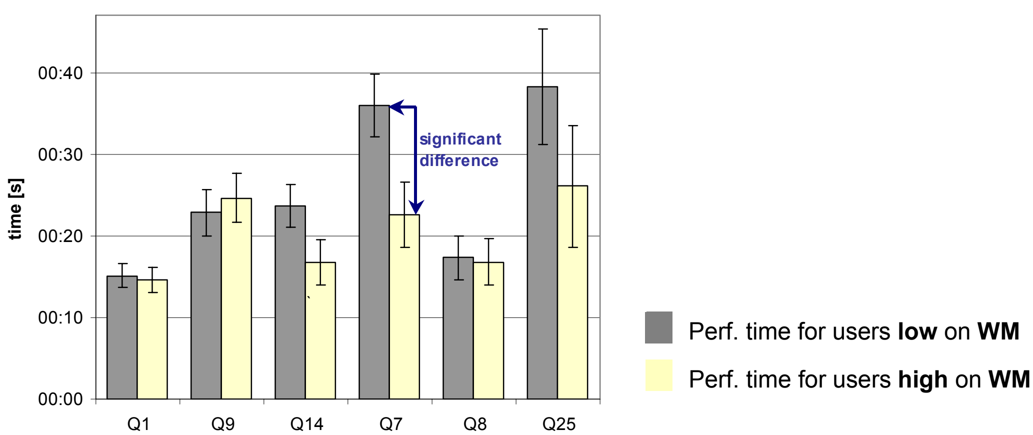


Figure 6.16. Effects of WM on performance time for each selected question.

6.5.3.1.5 Per-participant Analysis of WM Effects

To gain further understanding of factors influencing performance time, I analyzed transcribed study sessions for question 7. Question 7 was designed in such a way that the target message was at the top of the Inbox[1]. The fastest users did not re-sort the inbox, they employed two different ways of locating the target message: 1) visual scanning without (or in parallel with) moving the mouse pointer (users: #07, #25, #17), or 2) guided visual search by moving the mouse pointer along with their visual focus (users: #11, #24, #18). The slowest users failed to notice the target message, although it was right at the top of the inbox (users: #21, #08, #04). They either re-sorted by Task (users: #03, #08 and #04) or kept scrolling up and down (#21). All the slow users mentioned here (except user #04) were low on WM. They appeared not to scan visually in a systematic way. In other cases, slow users were apparently not sure about which strategy to choose, for example user #19 first tried to scan visually, then sorted by date, then by task.

A possible explanation is that they were “overwhelmed” by the amount of information they needed to process serially (systematic scanning of message headers required users to control their attention, an ability related to WM capacity) and employed instead a sorting strategy to compensate for their low WM.

Other slow users were apparently not sure about which strategy to choose, for example user 19sw first tried to scan visually, then sorted by date, then by task. This behaviour, again, may be attributed to limited ability to control attentional resources.

Time spent on question 7 was found to be positively correlated with sorting (Pearson’s r=.544, t=2.97, p=.007; Spearman correlation (ordinal by ordinal): =.652 t=3.94, p=.001). Performance time was also positively correlated with the amount of scrolling (Spearman correlation=0.496, t=2.22, p=.038, Pearson’s r=0.384, t=1.91, p=.07). Sorting was positively correlated with the amount of scrolling (Spearman correlation=.634, t=3.76, p=.001).

1. The message was at the top in date-sorting. Date-sorting was an initial sort order in 20 out of 24 cases.

In summary, users low on WM were overall slower. Their lower performance in the first session on the visual user interface can be attributed to learning both the task and the interface. The low-WM participants overall sorted more. The first plausible explanation is that, due to their lower working memory storage capacity, they needed to refer back to the information they had previously seen. The second plausible explanation is supported by the analysis of user behaviour on an individual question. The low-WM people have a more limited ability to control their attention, and therefore may have a greater difficulty in performing a systematic visual scan of information displayed in the inbox.

6.5.3.2 Effects of Flexibility of Closure

There was no interaction between user interface and FC. However, there was a significant two-way interaction effect of Task x FC on performance time in the second session ($F(2,40)=3.84$, $p=.03$, $\eta^2=.161$) (Figure 6.17). Performance times varied little between high and low levels of flexibility of closure (FC) for tasks "H" (26s and 31s for FC low and high respectively, this difference was not significant) and "D" (23s and 24s). In contrast, for task "M", users low on FC were significantly slower than users high on FC (an average of 27 seconds per question vs. 21 seconds).

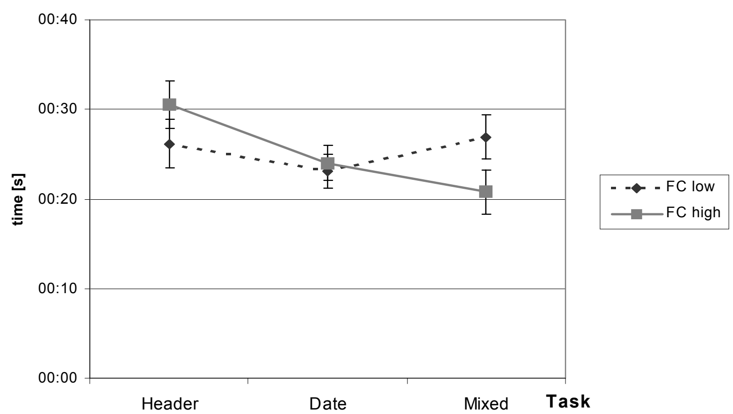


Figure 6.17. Effects of interaction Task * FC on time in second session.

Task "M" required users to first to find, then to keep in mind one type of information (e.g., date), relating it to other type of information (e.g., person's name). Apparently this task imposed more demands on cognitive processes related to the flexibility of closure.

6.5.3.3 Effects of Visual Memory (VM1 & VM2)

There were no significant interaction effects of visual memory and interface or task on performance time. A series of analyses of variance were then performed to determine whether or not visual memory (VM1 or VM2) and experimental conditions affected the amount of scrolling and sorting.

The interaction between UI and VM1 had a significant effect on scrolling in the second session ($F(2,40)=4.98$, $p=.037$, $\eta^2=.199$). As can be seen in Figure 6.18, there was no difference in scrolling between both interface conditions for participants low on VM1 (they scrolled an average of 386 & 346 pixels per question). In contrast, for participants high on VM1 there was a significant difference in scrolling between the two interfaces (562 and 267 pixels on UI Text & Visual respectively). No effects of VM2 on scrolling were found.

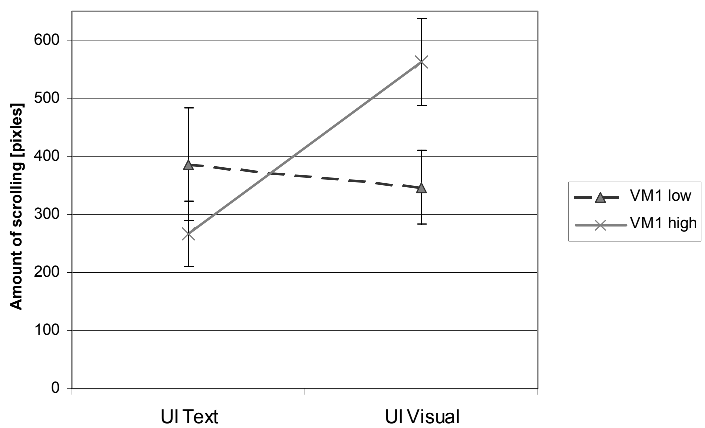


Figure 6.18. Effect of interaction UI * VM1 on scrolling (second session).

No interaction effects involving VM1 or VM2 on sorting were found. However, there was a significant main effect of VM2 on the total amount of sorting in both the first and the second session (Session 1: $F(1,20)=8.06$, $p=.010$, $\eta^2=.287$; Session 2: $F(1,20)=4.9$, $p=.039$, $\eta^2=.196$). Participants low on VM2 performed less sorting, while those high on VM2 sorted more (Figure 6.19).

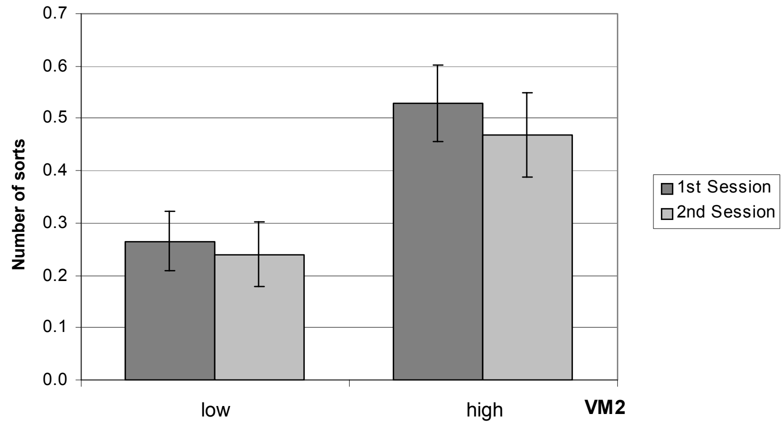


Figure 6.19. Main effect of VM2 on the total amount of sorting (both sessions).

People low on VM1 scrolled less in the visual interface, and people low on VM2 sorted less in all experimental conditions. A possible explanation is that users who are low on visual memory prefer to maintain a constancy in the visual field, thus they avoid changing contents of the display.

6.5.3.3.1 Analysis of Selected Questions

As described earlier, a detailed analysis was carried out on the six selected questions in order to gain insight into the observed effects. This section reports on the effects found on the visual memory.

There was a main effect of questions on scrolling ($F(3.2,70)=2.66$, $p=.052$, $\eta^2=.108$ (Figure 6.20). No significant effect of interactions between questions and cognitive abilities on the amount of scrolling were found.

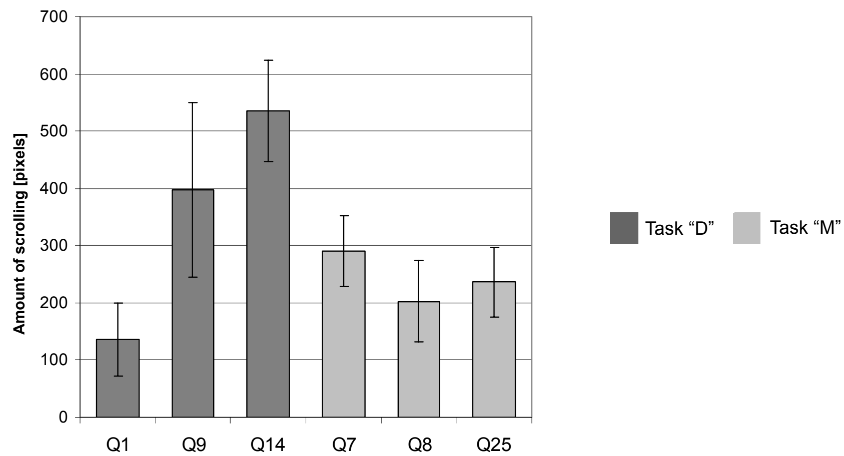


Figure 6.20. Amount of scrolling (pixels) per selected question.

The amount of total sorting for the six selected questions was not found to be significantly different (F < 1). However, a significant effect of interactions between the questions and cognitive abilities on the amount of sorting was found (Figure 6.21).

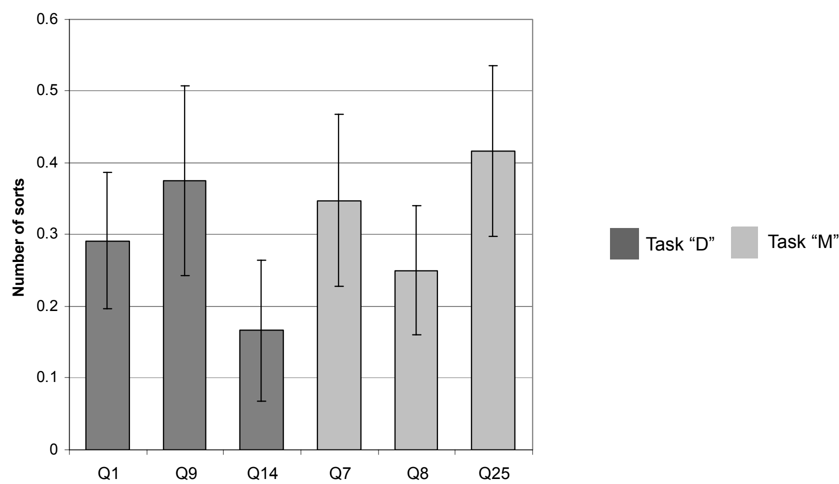


Figure 6.21. Amount of sorting (pixels) per selected question.

There was a main effect of VM2 on the total sorting (F(1,21)= 4.44, p=.047). Users low on VM2 sorted less (0.21 per question) while users high on VM2 sorted more (0.48). Further analysis (ANOVA) was performed to find the source of this significant difference. VM2 was found to have a significant effect on sorting for question 8 (F(1,22)=9.37, p=.006) and for question 25 (F(1,22)=6.93, p=.015) (Figure 6.22).

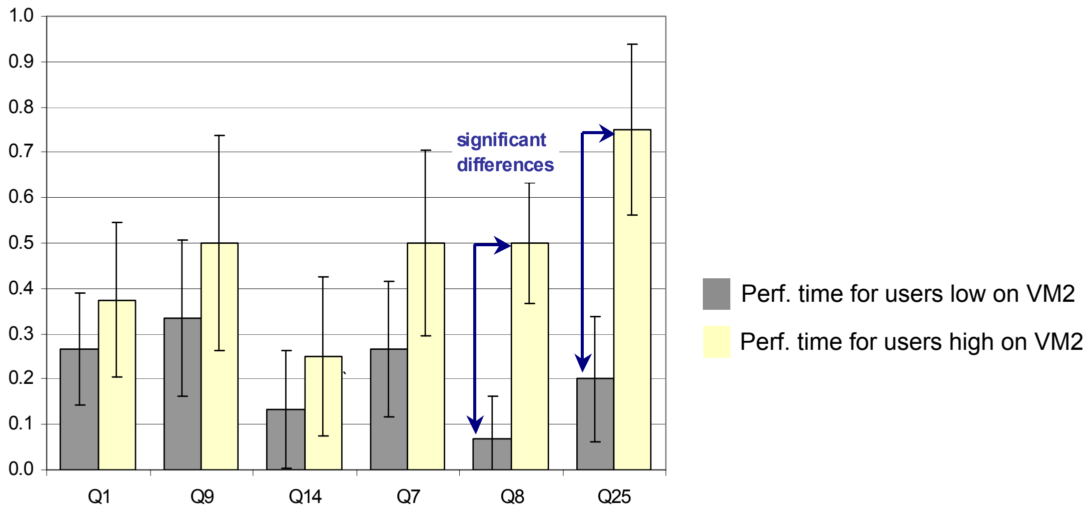


Figure 6.22. Sorting (total number of sorts per question) and VM2.

For question 25, there was also a significant main effect of user interface in which this question was presented ($F(1,16)=8.7$, $p=.009$, $\eta^2=.352$). Users performed an average of .64 sorts per question 25 in the textual interface vs. .43 sorts per question 25 in the visual interface. No higher order interaction effects were found.

For question 8, the "optimal" strategy to find the target message was to have the inbox sorted by a date column (either Start- or End-Date). Having the inbox sorted by date made it faster to find the target message (the message was then close to the top). In 8 cases out of 24, the initial sorting was different (Table 6.8). Six users who sorted in question 8 (users #8, #11, #19, #23, #25, #26) had the inbox initially sorted by a column other than one of the Date columns. Five of those users were high on VM2. Two other users (#6 and #15) had also non-date (the Task column) initial sorting, but they did not re-sort by Date. This can be, perhaps, explained by their low level of VM2.

User code	Initial sort	Re-sorted by	VM2 level
#2	End-Date		high
#3	Start-Date		low
#4	Start-Date		high
#5	End-Date		low
#6	Task		low
#7	End-Date		low
#9	End-Date		low
#10	End-Date		low
#12	End-Date		high
#13	End-Date		low
#15	Task		low
#16	End-Date		high
#17	End-Date		low
#18	End-Date		low
#20	End-Date		low
#21	Start-Date		low
#22	End-Date		low
#24	End-Date		low
#8	Task	Start-Date	high
#11	From	Start-Date	high
#19	Task	Start-Date	low
#23	Subject	Start-Date	high
#25	Subject	Start-Date	high
#26	Task	Start-Date	high

Table 6.8. Question 8: Sorting and levels of VM2 for all users.

For question 25, the "optimal" strategy was to sort the inbox either by the Task or by the Subject column. In all cases, except one (user #12) the inbox was initially sorted by Date (see Table 6.9). 9 out of 24 users re-sorted inbox by Task or Subject. 6 of those users were high on VM2, while 3 were low on VM2. The remaining 15 users did not re-sort the inbox in answering this question. Only 2 of these users were high on VM2, while 13 were low.

User code	Initial sort	Re-sorted by	Sorted > twice	VM2 level
#3	Start-Date			low
#5	End-Date			low
#6	End-Date			low
#9	End-Date		yes	low
#10	End-Date			low
#11	Start-Date		yes	high
#12	From			high
#13	End-Date			low
#15	Start-Date			low
#17	End-Date			low
#18	End-Date			low
#20	End-Date			low
#21	End-Date			low
#22	End-Date			low
#25	Start-Date		yes	high
#2	End-Date	Subject		high
#4	Start-Date	Task	yes	high
#7	End-Date	Task	yes	low
#8	Start-Date	Task	yes	high
#19	Start-Date	Task	yes	low
#23	Start-Date	Subject	yes	high
#24	Start-Date	Subject		low
#26	Start-Date	Task		high
#16	Start-Date	Subject & Task	yes	high

Table 6.9. Question 25: Sorting and levels of VM2 for all users.

I examined further those users who were high on VM2 (first group) or who did use sorting several times in other questions (second group), but who did not re-sort in question 25. In the first group, user #12 found message immediately (in spite of an "incompatible" sorting mode). User #11 first failed to see the target message because its header was displayed in a normal font weight, among message headers displayed in bold. This user performed exhaustive information search by opening several messages with subject lines containing the word "meeting". In the second group, user #9, moved the mouse pointer to guide visual search and found the target quickly. User #25 quickly found the target message after scanning visually. For those users sorting was unnecessary because they found information quickly.

All users who never sorted in those six questions, were low on VM2.

Time spent on question 8 was found to be positively correlated with sorting (Pearson's $r=.521$ $t=2.87$, $p=.009$; Spearman Correlation (ordinal by ordinal): $=.558$ $t=3.15$ $p=.005$). It was also positively correlated with the amount of scrolling (Spearman correlation=0.543, $t=3.03$ $p=.006$, Pearson's $r=0.714$, $t=4.78$, $p<.001$). For question 25, time was not found to be correlated with sorting ($t<1$, $p>.5$). However, time on question 25 was found positively correlated with the amount of scrolling (Spearman correlation=0.530, $t=2.93$ $p=.008$, Pearson's $r=0.374$, $t=1.894$, $p=.071$).

All three question (q7, q8, and q25), for which I found significant differences in performance time (presented in Section 6.5.3.1.4) or in sorting, were of type "M". Task "M" was earlier found to affect performance time, sorting and scrolling in the statistical tests that took into account all questions.

6.5.4 Effects of Strategy and Experience

Demographic variables such as email experience, and cognitive abilities such as working memory provide potential groupings of subjects. Another method of grouping subjects is to use cluster analysis, based on behavioural measures such as time taken, amount of scrolling, etc. as the dependent measures, and subjects as the observations to be clustered. There were two observations per subject in the cluster analyses that was carried out, one observation for each of the interfaces. The general expectation was that strategies would be consistent within, but not across subjects.

K-means cluster analysis was carried out (as implemented in SPSS) with the following behavioural measures: performance time, number of opened messages, amount of scrolling and sorting for each task. Prior to the analysis, each of the measures was converted to a standardized normal equivalent (z-scores) in order to remove any affect of scale differences prior to the clustering. One observation was an outlier (it formed a cluster containing just itself when included in the analysis) and was removed for this analysis.

A two cluster solution was chosen as giving the best grouping of the remaining 47 observations. In 20 of the 23 cases, the two observations (one per interface) for the person were assigned to the same cluster. Thus strategy, as represented by the clusters, tended to be consistent across the interfaces. Analysis of variance was used to interpret the clustering results. There were significant differences between the clusters in terms of time taken for the three tasks, and the amount of scrolling and sorting that was used as shown in Table 6.10. The two variables that did not differ significantly between the clusters involved numbers of messages viewed for task "M", and for tasks "H" and "D" combined.

	F(1,45)	**p value**
Zscore (TIMEGCT)	13.326	0.001
Zscore (TIMEGDT)	34.135	<0.001
Zscore (TIMEGMT)	9.522	0.003
Zscore (MVIEWNMT)	0.01	0.921
Zscore (SCROLLMT)	5.85	0.02
Zscore (MVIEWCD)	0.519	0.475
Zscore (SCROLLCD)	8.033	0.007
Zscore (SORTTOCT)	19.783	<0.001
Zscore (SORTTODT)	23.294	<0.001
Zscore (SORTTOMT)	13.161	0.001

Table 6.10. Results for cluster analysis.

Table 6.11 shows the cluster centres, indicated as z-scores (e.g., a score of.88 indicates that the value of the corresponding variable in the cluster centre is .88 standard deviation units above the mean for that variable). As can be seen from inspection of Table 6.11, people in cluster 1 took more time to answer the questions, and they used more scrolling and more sorting. One plausible interpretation of these results is that people in cluster 1 expended more effort in performing the tasks. The clusters obtained in this analysis will be called "Performance & Effort Clusters" or PE-Clusters.

	PE-Cluster 1	PE-Cluster 2
Zscore (TIMEGCT)	0.61553	-0.36713
Zscore (TIMEGDT)	0.88152	-0.48832
Zscore (TIMEGMT)	0.15087	-0.27016
Zscore (SCROLLMT)	0.42081	-0.27208
Zscore (SCROLLCD)	0.50883	-0.30026
Zscore (SORTTOCT)	0.78173	-0.37343
Zscore (SORTTODT)	0.81219	-0.42029
Zscore (SORTTOMT)	0.67377	-0.32437

Table 6.11. Cluster analysis - distance from the cluster centers.

T-tests were then used to assess how cognitive abilities varied between the clusters. Differences were found for CS1 (p=.045), VM1 (borderline p=.074), VM2 (p=.01) and WM (p=<.001). My interpretation of these results is that there are systematic differences between subjects in terms of how they carried out the tasks, and that these differences are attributable (at least in part) to differences in cognitive abilities.

Cognitive Ability	PE-Cluster 1	PE-Cluster 2
CS1	low	high
WM	low	high
VM1	high	low
VM2	high	low

Table 6.12. Cognitive abilities that differed significantly between clusters.

Table 6.12 shows how people low and high on these four cognitive abilities were distributed between the two clusters. PE-Cluster 2 participants, who tended to be faster and expended less effort (as measured by scrolling and sorting), were high on speed of closure and working memory, while PE-Cluster 1 participants were high on visual memory.

Correlational analyses were then used to assess relationships between the PE-clusters and the other variables that were measured. One of the strongest relationships was between PE-Cluster and Email experience ($r = 0.769$; $p<.0001$). Eight of the 11 people with low email experience were in PE-Cluster 1, whereas all the 13 people with high email experience were in cluster 2.

There was also a significant correlation between working memory and cluster ($r= 0.473$; $p=0.02$). Seven of the eight people with low working memory were in PE-Cluster 1. Ten of the 16 people in PE-Cluster 2 had high working memory. However, there was also a significant correlation between working memory and Email experience ($r=0.51$, $p=.01$). Nine of the 13 people with low working memory had low Email experience, whilst nine of the 11 people with high working memory had high Email experience.

For total number of sorts used, there was a significant two-way interaction between user interface and PE-Cluster ($F(1,22)= 6.024$; $p=0.022$). More sorting was carried out by users in PE-Cluster 1, particularly with the text interface (an average of .69 sorts per question vs. .43 sorts per question in the visual interface, and for cluster 2 users, an average of .26 and .18 sorts per question for the text and visual interfaces respectively).

There was also a significant two-way interaction between Task and PE-Cluster for the amount of sorting by date ($F(1,22) = 4.91$; $p=0.012$). For task "D" PE-Cluster 1 users had a disproportionately high number of sorts by date as compared both to PE-Cluster 2 users in other tasks and to PE-Cluster 1 users in general (Figure 6.23).

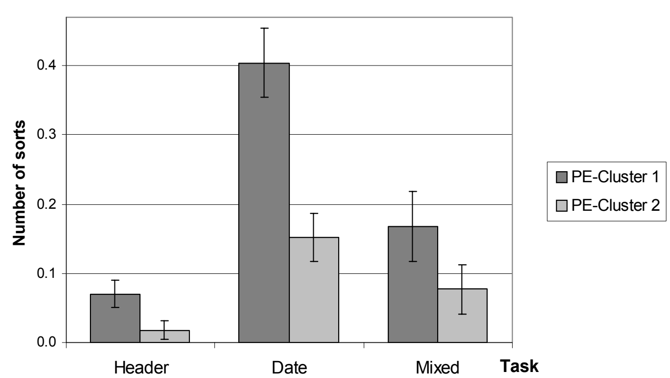


Figure 6.23. Interaction Task * PE-Cluster for sorting by dates.

For the sort by task measure there was a significant three-way UI * Task * PE-Cluster interaction (F(1.9, 42)=6.248, p=0.005). Sorting by task was disproportionately high for PE-Cluster 1 users performing task "M" in the text interface, as compared to all other combinations of cluster, task, and user interface (Figure 6.24).

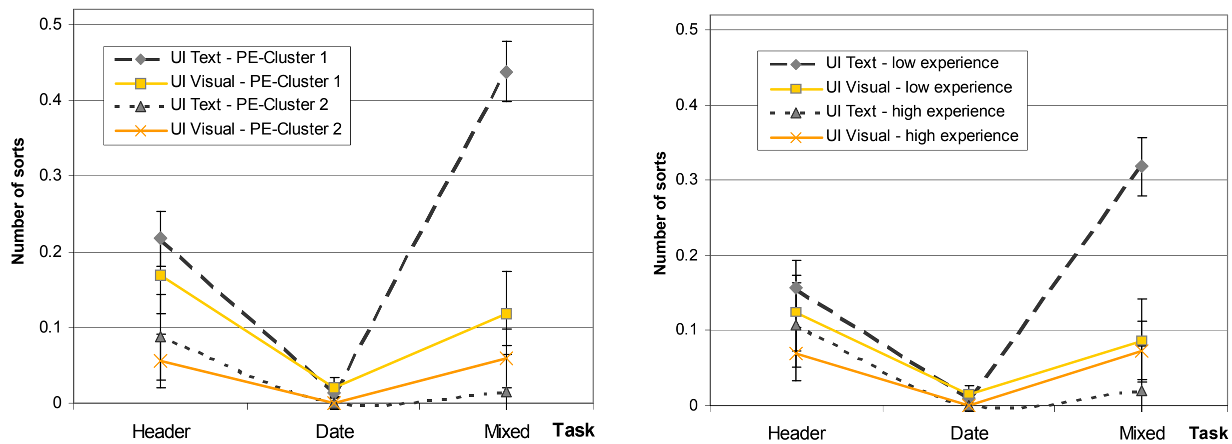


Figure 6.24. Effects of UI*Task*PE-Cluster (left) and UI*Task*Email Experience (right) on sorting by the Task-column.

Since there was a strong correlation between the clusters and email experience, effects of email experience were also examined.

For sorting by task as the dependent measure, the three-way interaction between user interface, type of task, and level of email experience was significant (F(1,22)=4.25, p=.02). As shown in Figure 6.24, there was a disproportionate amount of sorting by the task-column in task "M", but only for people with low levels of email experience. The more email experience people had, the faster they were in the text interface (r=-0.505, p=.012). The more email experience people had the less they sorted in the text interface (r=-0.458; p=.024).

6.5.5 Effects of Cognitive Abilities on Email Habits

Section 3.3.1, in Chapter 3 which described the field study, presented a cluster analysis in which participants were grouped based on the *Prospective actions* items obtained from a survey on their email habits. A similar cluster analysis was performed for participants of the WebTaskMail study. This analysis was performed in order to examine if the behavioural differences between people described earlier as "email handling styles", with two distinct styles 1) keep prospective information in email; 2) transfer prospective information from email, could be attributed to differences in demographic measures, cognitive abilities or email experience.

The k-means cluster analysis that was carried out, followed the same procedure as presented in the previous section (Section 6.5.4). A two cluster solution was chosen as giving the best grouping of participants (7 and 16[1] participants in two clusters). Analysis of variance was used to interpret the clustering results. There were significant differences between the clusters in terms of all, except two, email habit variables used, as shown in Table 6.13.

	F(1,21)	**p value**
Zscore (WRDMAIL)	7.261	0.014
Zscore (MAILINTR)	9.988	0.005
Zscore (SEARCH)	4.097	0.056
Zscore (EVTTRNSF)	2.048	0.167
Zscore: (KEEPEVT)	19.478	0.000
Zscore (TODTRNSF)	3.196	0.088
Zscore: (KEEPTODO)	18.361	0.000
Zscore (REMINDE)	0.218	0.645
Zscore (SLFREMND)	6.947	0.015

Table 6.13. Results for cluster analysis.

Table 6.14 shows the cluster centres, indicated as z-scores. The table also includes a descriptive interpretation of the differences between the two clusters. The clusters obtained in this analysis will be called "Email Style Clusters" or ES-Clusters. As can be seen from inspection of Table 6.14, people in ES-Cluster 1 seem to have more control over their email behaviour, by not letting incoming emails interrupt other activities and

1. Email survey data was partially missing for one of the 24 participants, thus N=23.

by setting specific times to read email, they tend not to use email to handle prospective messages. In contrast, people in ES-Cluster 2 treat email as a *habitat*, letting incoming interrupt other activities and reading messages all the time, they also tend to use email to keep and handle prospective messages.

	ES-Cluster 1	ES-Cluster 2	ES-Cluster 1 description	ES-Cluster 2 description
Zscore (WRDMAIL)	-0.749	0.328	read email at specific times	read email all the time
Zscore (MAILINTR)	-0.839	0.367	email does NOT interrupt other tasks	email interrupts other tasks
Zscore (SEARCH)	-0.597	0.261	do NOT search in email	search in email
Zscore (EVTTRNSF)	0.441	-0.193	do transfer events from email	(insignificant) do not transfer events from email
Zscore: (KEEPEVT)	-1.026	0.449	do NOT keep events	keep events
Zscore (TODTRNSF)	0.537	-0.235	transfer to-do's from email	do NOT transfer to-do's from email
Zscore: (KEEPTODO)	-1.010	0.442	do NOT' keep to-do's	keep to-do's
Zscore (REMINDE)	-0.150	0.066	(insignificant) do NOT use email as a reminder	(insignificant) use email as a reminder
Zscore (SLFREMND)	0.737	-0.323	send self-reminding email messages	do NOT send self-reminding email messages

Table 6.14. Distance from the cluster ES-centers and description of clusters.

The obtained ES-clusters are similar to those presented in Table 3.4 (Chapter 3).

T-tests were then used to assess how demographic measures, cognitive abilities and email experience varied between the ES-clusters. Significant differences were found for flexibility of closure - FC (p=.001) and for email experience (p=.011).

Measure	ES-Cluster 1	ES-Cluster 2
FC	low	high
Email Experience	less experience	more experience

Table 6.15. Significant different measures between the clusters.

As can be seen from Table 6.15, people grouped in ES-Cluster 2 tended to have more email experience and were high on FC. Extracting information from the variety of email messages may be more demanding on people low on FC. Therefore, the low-FC users do not keep those different kinds of information in one place (in email), but rather transfer information to different applications designed to handle specific information types (e.g., a day timer for scheduled events). Two plausible explanations were identified for why people with more email experience were found in ES-Cluster 2. Those using email for a longer time, may be receiving more email messages and a wider variety of messages types. Thus, there is a higher probability that they read email more often and keep the prospective information in email.

Table 6.16 shows cross-tabulation of membership in PE-Clusters and ES-Clusters.

	PE-Cluster #1	PE-Cluster #2	total
ES-Cluster #1	4	3	7
ES-Cluster #2	4	12	16
(missing data)	-	1	1
total	8	16	24

Table 6.16. Crosstab for performance and email clusters.

Membership in the "fast and less-effort" PE-Cluster #2 overlaps to a large degree with the membership in the "email habitat containing prospective message" ES-Cluster #2. 1While the membership in PE-Cluster #1 is split between both ES-Clusters 1 and 2.

6.5.6 Email Experience

As reported throughout the analyses presented in this chapter, email experience (self-reported email use in years) was found to be correlated with WM and PE-Cluster. Further analyses were performed to check whether there was a significant different between the mean values of other variables when grouped by two levels of email experience. A difference in mean was found for: PE-Cluster ($p<.001$), ES-Cluster ($p=.02$), CS1 ($p=.016$), WM (p=.01). Table 6.17 shows the directions of changes between these values when grouped by two levels of email experience (low / high).

Measure / Variable	**Email Experience**	
	Low	**High**
PE-Cluster	PE-Cluster #1	PE-Cluster #2
ES-Cluster	ES-Cluster #1	ES-Cluster #2
CS	low	high
WM	low	high

Table 6.17. Significant differences between means for measures grouped by two levels of email experience.

6.5.7 Subjective Evaluation of Interfaces

Subjective evaluations of both interfaces, performed after each interface was used, were strongly correlated (r=0.778; p= 0.005). Participants more than agreed (mean 1.25 on a scale of <-2, 2>, where 0 corresponded to neutral, and 1 corresponded to agree) that both WebTaskMail interfaces were easy to use, that they might reduce workload associated with handling pending tasks in email, and that they would help them to view to-do's and events. For both UIs, participants answered between neutral and agree that they prefer to use WebTaskMail to a standard email program (like Outlook) and to a calendar program.

Participants expressed a slight preference (0.5 vs. 0.2 p=.043 and 0.9 vs. 0.5; p=.002 for four relevant questions about the visual interface) for using WebTaskMail-Visual to view to-do's with deadlines than to view scheduled events

One of the questions was answered significantly different for UI-Text and UI-Visual. (as demonstrated by discriminant analysis F(1,46)=4.589 p=.038). Question 7: “The WebTaskMail program provides a better overview of all pending tasks than the standard view of email messages (e.g., as provided by Outlook)”. For the textual interface, the average agreement with this question was between neutral and agree (0.67), while for the visual interface the agreement was between agree and strongly agree (1.21). Thus, providing at-a-glance overview of tasks in my design was successful, at least in terms of its subjective evaluation after participants used the interface in the course of this study.

When comparing the two interfaces, in the questionnaire administered at the end of the second session, participants agreed that visual interface was easier to use than the text interface, and expressed their preference for using the visual to handle and view to-do's and events. Participants expressed their belief that their performance was better using the visual interface, but they were neutral about which interface was easier to learn.

6.6 Discussion

6.6.1 Interface Design and Tasks

While the visual interface was preferred by participants to the textual interface, there were no clear benefits of the visual interface in terms of better user performance. The differences in performance time between the two user interfaces were significant only in the first session during task interface learning phase. The “Mixed” task (M) was performed more slowly during the first session on the visual interface.

Participants sorted the most in the first session on the textual interface, while they sorted the least in the first session on the visual interface, and about the same in the second session on both interfaces. They sorted more on the “Header” task (H) than on the “Date” task (D) or on the “Mixed” task. One possible explanation for this result is, that once the participants learned the task (after the first session) the amount of sorting did not depend on the interface, but only on the task.

6.6.1.1 Differences in Performance on Tasks

The observed differences in performance on tasks were due to the differences in interface design as well as to the differences in tasks. The tasks differed in the type of information to be found by participants.

The visual interface was designed for task “Date”, which was confirmed by the fast performance on task “Date” (in the second session, that is after the task learning).

Task “Header” was the slowest and required more sorting on task “Header”. Task “Header” target information type could be found either in the From- or in Subject-column. However, it had not always referred to the first word in the Subject-column, thus the alphabetical sort-order of the From/Subject-columns did not necessarily correspond to the order of target information. Hence slower performance on task “Header” in both interfaces.

Several differences in performance on task “Mixed” were observed. In particular, in the first session, task “Mixed” was slower in the visual interface, while in the second session people high on flexibility of closure (FC) were faster on this task. Such differences in performance were also confirmed by the detailed analysis of the selected questions.

By design, task “Mixed” was more complex, it involved two types of information. Task “Mixed” involved finding header information (as for task “Header”) and then locating an associated date information (e.g., event's start-date, similarly as for task “Date”) (or vice-versa). To perform the first part of the task, a number of participants used sorting by the Subject line or by the Task. After finding the target message, they needed to read the corresponding date information. In the sorting order they had already selected (e.g., Subject or Task), there was no secondary date order. Consequently, when sorted by Task (for example), messages within the group marked by the Task keyword “meeting” were seen in the order of their arrival. To read the date in the text interface, subjects needed to scan a range of textual date fields, while in the visual interface, participants used the horizontal timeline with a vertical line to read the dates. Thus this task required integrating events (represented by squares) located at different vertical positions (belonging to different rows, that is to different messages) within a group into one coherent timeline. Ignoring the vertical ordering, and focusing on the horizontal order, may have required more cognitive effort, thereby slowing participants down, especially during the first session while they were still learning the task and the visual interface. Consequently, in this task, the date reading process was slower in the visual interface. Evidence of the effect of cognitive abilities may also support this analysis. In the second session, participants high on flexibility of closure (responsible for extracting pieces of information from a whole object) were faster.

The study results provided evidence that subtle and relatively small differences in task details may significantly impact performance. Although all of the tasks “Header”, “Date”, & “Mixed” involved finding information, they differed with respect to type of the target information. The “interaction” between the type of target information and the interface design affected performance measures used in the study.

6.6.2 Cognitive Abilities

In contrast to the previous study (Chapter 5), none of the interactions between user interface and cognitive abilities with time as the dependent measure were significant. Where interactions with cognitive abilities were observed (with respect to sorting and scrolling) the effects were mixed, with less evidence for disadvantages due to having low levels of some cognitive abilities than in the earlier study.

Cognitive abilities were found to impact different dependent measures and to interact in different ways with the user interfaces as well as with the tasks. Working memory and flexibility of closure had effects on performance time, while visual memory and, again, working memory, had effects on user interactions involving manipulation of the visual field, such as scrolling, and sorting.

Both working memory (WM) and visual memory (VM2 - memory position on 2D map) had a main effect on sorting in both sessions. These effects are possibly related to different phenomena. A plausible explanation for why people low on VM2 sorted less is, that they wanted to maintain a constancy of the visual field (visual momentum - Woods, 1984), while people high on VM2, who had a *better* visual memory (as measures by this test), did not have such a need.

Participants low on WM sorted more, while those high on WM sorted less. Two different reasons were identified for the differences in sorting between the low and high WM participants. First, low-WM people have a lower working memory storage capacity, therefore they may need to do more sorting to “refresh” their WM store (serving as an “input buffer”) more often. The detailed analysis of the selected questions suggested another plausible reason. People low on WM may be performing more sorting because of their lower ability to control attention. They are less able to scan a visual display systematically, and, after not being able to find the target information for some time, switch to a different view.

Performance and Effort Clusters were also found to impact sorting. Participants from PE-Cluster #1 were found to sort disproportionately more by the Date-column on the “Date” task and by the Task-column on the “Mixed” task. One possible interpretation: people in PE-Cluster #2 did not need the guidance of sorting - they were scanning visually in a more systematic way (they tended to have higher WM).

6.6.2.1 Why Does Low Working Memory Impair Email Performance?

Level of working memory appears to be an important determinant of email handling performance. While there was evidence of a learning effect, lower WM users continued to perform more slowly than their high WM counterparts in the second session. In contrast, the user interface effect that was apparent in the first session was no longer statistically significant in the second session. Thus WM had a more lasting effect on performance in this study than did type of user interface.

The effect of WM also appeared to be relatively independent of type of task in this study. This was in contrast to the interaction that was found between the type of user interface and task. Thus the detrimental effect of low WM on email handling performance appears to be robust, and relatively task independent (at least in terms of the three task types used in this study).

A detailed analysis of the behaviour of users with low WM suggests that they have a problem in picking out relevant information quickly. While it was beyond the scope of this study to pinpoint the precise nature of this difficulty, it is possible that this difficulty is related to the attentional aspect of WM (Kane et al., 2001), with low WM users having difficulty in ignoring irrelevant and distracting information in the inbox. Consistent with this type of explanation, the relatively slow performance of low WM users might be attributable to the distracting effects of visual presentation of task start and end times and the vertical "date-cursor" (Figure 4.8 in Chapter 4).

Low WM users are more reliant on user interface functions such as sorting to compensate for the deleterious effects of their low WM. This explanation suggests that careful design of the interface may improve the lot of people with low WM, by speeding up their learning of email handling tasks, and by reducing the amount of effort they are required to expend in order to achieve satisfactory performance.

In contrast, there was no performance disadvantage for low WM users (versus high WM) in the text interface, presumably because it was more familiar and they had learned to cope with it, and/or there was less distracting visual information.

The results imply an important and multiple role played by working memory in learning, storing information, and attention control. Working memory thus appears to be one of the most critical factors in the interaction design. Interface design taking into account limitations of working memory has a high chance of yielding usable results.

6.6.3 Participant Groupings

The study found evidence of two different groupings of participants. In the first, participants differed in terms of the amount of time and effort (measured as two types of interactions with inbox: scrolling and sorting) they expended to perform the task. In the second, participants differed in terms of their email behaviour with respect to keeping or transferring prospective messages. The distinction between the *Performance & Effort Clusters,* created by the first grouping, was also related to differences in cognitive abilities

(CS1, WM, VM1, & VM2) and email experience. These differences between cognitive abilities were related to the interaction and main effects of cognitive abilities that were observed in this study.

The distinction between the *Email-Style Clusters* was related to differences in flexibility of closure (FC) and (again) email experience. Members of ES-Cluster #2 tended to have more email experience and were high on FC. Extracting information from the variety of email messages may be more demanding on people low on FC. Therefore, the low-FC users might not keep those different kinds of information in one place (in email), but rather transfer information to different applications designed to handle specific information types (e.g., a day timer for scheduled events). Two plausible explanations were identified for why people with more email experience were found in ES-Cluster 2. Those using email for a longer time may be receiving more email messages and a wider variety of messages types. Thus, there is a higher probability that they read email more often and keep the prospective information in email.

Chapter 7

Conclusions, Contributions and Future Work

"The important thing in science is not so much to obtain new facts
as to discover new ways of thinking about them."
Sir William Bragg

7.1 Research Summary

This research was motivated by the practical goal of helping email users to process messages more effectively. Of particular interest were those messages that are kept in email inboxes because they refer to the future and to pending tasks, that is, tasks involving future activities.

A field study examined those practices of email users that are related to handling messages containing references to the future. Results from the study demonstrated individual differences in email handling styles. One group of users kept *prospective* messages in email and used the email inbox as a reminder for future events. The other group transferred such messages out of their email programs to other applications (e.g., calendars). Email programs, however, were not designed to handle prospective information. As noted earlier in Chapter 3, users performed additional actions to replace "the missing" email functionality. To facilitate the monitoring and retrieval of prospective information from email messages, a more visual kind of email user interface was suggested.

Consequently, two user interfaces were designed in the course of this research. The TaskView interface displayed messages that carry pending tasks arranged on a two-dimensional grid. The WebTaskMail interface, developed later, in addition to displaying a timeline of pending tasks (events and to-do's), provided a vertical *date reading line* and added more space for email message headers.

Two user studies were conducted to test the hypothesized benefits of the visual representation employed in the user interfaces. The first goal of the user studies was to evaluate whether the designed visual representation of prospective messages indeed made users more efficient. Task performance was assessed on a user interface with and without the more visual of the representations. Thus, in each study, two email interfaces were used (a more visual interface and a more traditional textual email interface). The second goal of the user studies was to examine differences in performance between user groups that varied in their levels of cognitive abilities selected for their likely influence on email performance.

7.2 Summary of the Results

7.2.1 User Interface Design and Task Selection

The selected information elements were designed to be more *visible,* in order to facilitate monitoring and retrieval of prospective information from email messages. For the task that required finding date-related information (i.e., the "Date" task), task performance on both of the more visual interfaces (TaskView and WebTaskMail) was faster than on the more traditional textual interfaces (results are summarized in Table 7.1). Thus, the interfaces worked as expected for the task they were designed to support. For other tasks, the results were mixed. The "Header" task, which required finding textual information in the email header (either in the message sender field or in the message's subject line), was performed more slowly in the visual interface (in the first study). However, in the second study, performance time on this task was approximately the same in both interfaces. This accomplishment can be attributed to the redesign of the visual interface, and also to making the two study interfaces more similar[1]. The first study used a commercial, off-the shelf program, Microsoft Outlook, as the textual interface, while the visual interface was implemented as a (prototype) Java application. In contrast, in the second study both interfaces were implemented using the same software technology (a web-based implementation, both programs running within an Internet browser) and differed only in how the pending tasks' temporal attributes were visually presented.

The third task, "Mixed", introduced in the second study, favoured the more textual interface. Users on the "Mixed" task in the textual interface were approximately as fast as users on the "Date" task in the visual interface. Why? Task "M" was designed to require

1. Another factor might have contributed to reducing the difference in performance on task "H". In the second study, this task was designed so that it did not require users to view message content.

integration of the two types of information: "Header" and "Date". The two types of information were represented in the same way in the textual interface, while they were represented in two different ways (textual and graphical) in the more visual interface. Integration of the two different types of information probably made users less efficient in the visual interface.

The differences in performance on user interfaces and tasks were such that each interface's advantages on one task compensated for its disadvantages on another task. As a result, no interface was significantly faster overall. Thus no main effects of user interface were found. One exception was the learning effect during the first session in the second study, where the visual interface was slower (by 10% or 3s[1]) than the textual interface.

Information finding was used as a reference task for evaluating email interfaces. Three variations of the information finding task were created. The tasks differed in the type of target information to be found. Target information was chosen in such a way as to enable comparison of performance on the two types of user interface.

In both studies (in study one — both sessions, and in study two — second session only), type of task had a significant effect on performance time. The "Header" task was found to be slower than the other two tasks. An explanation can be sought in comparing the target information types involved in each task. The "Date" task and the "Mixed" task involved date information with a well defined (chronological) order[2]. The "Header" task involved sender or subject information, which can be sorted alphabetically. However, the order of these information types did not necessarily correspond to an alphabetical ordering of target information. For example, the target information could be a part of a subject line and could be expressed using a different wording. Thus, an alternative characterization of the tasks is:

1. The differences in performance times found in the two studies were generally between 3 and 15 seconds. This results are significant because information finding tasks are frequently performed as a part of higher-level email tasks.
2. The "Mixed" task involved both types of information.

1. “Header” task—task that deals with information without a natural order;
2. “Date” task—task that deals with information with a well defined natural order;
3. “Mixed” task—task that deals with both kinds of information and integrates them.

7.2.2 Impact of Cognitive Abilities

There was a complex pattern of cognitive ability effects obtained in this research (see Table 7.1). Some of these effects were related to learning, and others were independent of learning. Cognitive abilities were found to impact different dependent measures and to interact in different ways with the user interfaces, as well as with the tasks. Working memory and flexibility of closure had effects on performance time, while visual memory and working memory, had effects on user interactions involving manipulation of the visual field, such as scrolling and sorting.

In study #1 (Chapter 5), where the interface differences were larger, the cognitive abilities interacted significantly with type of user interface (with speed of performance as the dependent measure), whereas in study #2 the cognitive abilities did not (Chapter 6).

7.2.2.1 Flexibility of Closure Effects

In the second study, it was found that levels of flexibility of closure interacted significantly with type of task in affecting performance time. This suggests that even if interfaces can be designed that do not in themselves create a disadvantage for people with low levels of some cognitive abilities, those abilities may still affect the performance of certain types of task. While the results will need to be replicated in future studies, they hint at the complexity of potential interactions between tasks, interfaces (representations), and abilities. In the second study, the “Mixed” task questions were answered more slowly by users with low flexibility of closure. Performance of people at different levels of flexibility of closure was differentially affected by the need to integrate different information types in the “Mixed” task, but not by the differences in information representation (different user interface conditions). Apparently this task imposed more demands on cognitive processes related to flexibility of closure. Flexibility of closure was the only cognitive ability found to interact with task (in the second study).

7.2.2.2 Working Memory Effects

A detailed analysis of the behaviour of users with low working memory suggests that they have a problem in picking out relevant information quickly. While it was beyond the scope of this research to pinpoint the precise nature of this difficulty, it is possible that this difficulty is related to the attentional aspect of working memory (Kane et al., 2001), with low working memory users having difficulty in ignoring irrelevant and distracting information in the inbox. Consistent with this type of explanation, the relatively slow performance of low working memory users might be attributable to the distracting effects of visual presentation of task start and end times and the vertical "date-cursor" (Figure 4.8 in Chapter 4).

Low working memory users are more reliant on user interface functions such as sorting to compensate for the deleterious effects of their low working memory. This explanation suggests that careful design of the interface may improve the lot of people with low working memory, by speeding up their learning of email handling tasks, and by reducing the effort they require to achieve satisfactory performance. Learning in the first session was found to adversely affect performance time in the visual interface for participants low on working memory. In contrast, in the text interface, there was no learning disadvantage for low working memory users (versus high working memory). Perhaps the text interface was more familiar and users had learned to cope with it, and/or there was less distracting visual information.

The results imply an important and multiple role played by working memory in learning, storing information, and attention control. Working memory thus appears to be one of the critical factors in interaction design. Interface designs that take into account the limitations of working memory should lead to a more inclusive and usable email applications. Level of working memory was found to be correlated with amount of self-reported email experience.

Table 7.1 shows the main significant results of both user studies.

Effect		TaskView - User Study #1	WebTaskMail - User Study #2
UI - main effect		---	*1st session* UI-Visual slower (3 sec.)
Task - main effect		*both, 1st and 2nd sessions* task-H slower	*2nd session* task-H slower, D and M about the same
UI * Task		*1st & 2nd session* fastest: UI-Visual & task-D slowest: UI-Visual & task-H	*2nd session* fastest: UI-Visual and task-D fastest: UI-Text and task-M slowest: UI-Text and task-H
WM	**UI * WM**	---	---
	UI * Task * WM	*1st session* low-WM slow in UI-Visual *on task-H*	*1st session* low-WM slow in UI-Visual high-WM fast in UI-Visual
	WM	---	*both sessions* low-WM slower than high-WM low-WM sort more than high-WM
FC	**UI * FC**	*2nd session* low-FC slow in UI-Text *on task-D*	---
	Task * FC	---	*2nd session* high-FC faster than low *on task-M*
	FC	---	
VM	**UI * VM**	---	*2nd session* high-VM1 scroll more than low *in UI-Visual*
	Task * VM	*2nd session* low-VM slow *on task-H*	---
	VM	---	*both sessions* low-VM2 sort less than high

Table 7.1. Summary of the main results from the two user studies.

7.2.2.3 Visual Memory

Both types of visual memory tested in the studies (memory for 2D shapes — VM1, and memory for locations on 2D maps — VM2) had effects on user interactions involving manipulation of the visual field, such as scrolling (VM1) and sorting (VM2). Generally, users high on visual memory performed more interactions, that is, changed their visual field more often than users who were low on visual memory. A possible explanation is that low visual memory people wanted to maintain the constancy of their visual field, while high visual memory people did not have such a need

7.2.2.4 Email Experience and Other Factors

The present findings show that email behaviours change depending not only on the tasks being performed and the email interfaces being used, but also on individual characteristics. In particular, three general factors affecting email usage were identified (Figure 7.1). In both studies, cognitive abilities (e.g., working memory and flexibility of closure) are implicated in determining performance, particularly with the "Mixed" task questions, on the visual interface that was used. Email experience was also found to have a strong effect on performance. Another possible explanatory variable is the type of participant that is used, as determined by clustering users according to their behaviour. Thus cognitive abilities, participant types, and email experience are all potential predictors of email performance. However, since these factors were found to be correlated with each other, it remains a task for future research to determine which of these factors are primary causes.

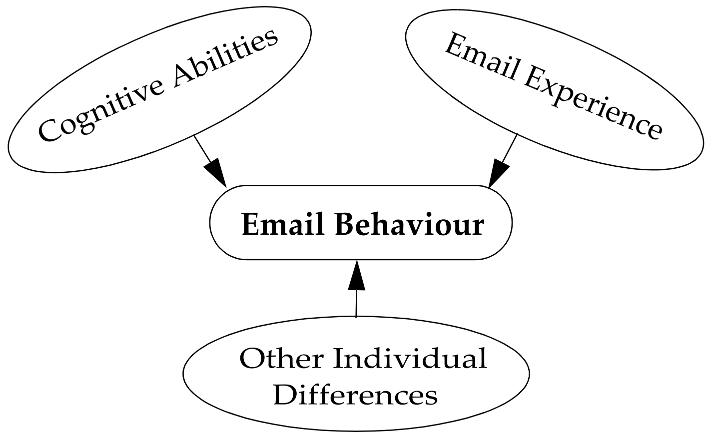


Figure 7.1. Factors affecting email strategies.

7.3 Methodology

This research results suggest that it is important to consider alternative interfaces for different population groups and for different tasks, i.e., to accommodate individual differences in ability. Egan proposed three steps in designing interfaces to accommodate individual differences (Egan, 1988), which are listed below.

1. Ascertain what user characteristics predict the biggest differences in performance.
2. Isolate the sources of variation at the task or interface component level.
3. Redesign tasks or interfaces to minimize their offending components so that the benefits for all user groups can be maximized.

Neuwirth et al. (1998) proposed a five step evaluative process for designing user interfaces so that important (benchmark) tasks could be carried out efficiently.

1. Develop benchmarks tasks (designed to capture aspects of real-world tasks);
2. Observe subjects performing the benchmark tasks;
3. Develop prototypes to overcome these difficulties;
4. Measure and compare the performance of subjects completing the tasks with and without the aid of the prototype;
5. Make changes to the prototype based on the results of the comparison, and repeat the process.

Approach	Neuwirth: task-centric	Egan: user-centric	This thesis: user-centric reference-task-based
Goal	Develop or modify user interface to improve user performance on (a) specific task(s)	Develop or modify user interface or task(s) to minimize the differences in performance for all users	Develop or modify user interface to minimize the differences in performance for all users with respect to selected tasks
Steps	N1. Develop benchmarks task(s)		G1. Select and develop reference tasks and establish user characteristics (individual differences) that predict the biggest differences in performance
		E1. Ascertain what user characteristics predict the biggest differences in performance	
	N2. Observe users performing the benchmark tasks	E2. Isolate the sources of variation at the task or interface component level	G2. Study user performance, focusing on differences between user groups (e.g., characterized by different levels of cognitive abilities) at task and user interface level
	N3. Develop (or modify) user interface prototypes to overcome these difficulties	E3. Redesign task or interface to minimize their offending components so that the benefits for all user groups can be maximized	G3. Redesign user interface to minimize the differences between user groups across the selected tasks
		E1-R. (Optionally) Repeat step E1.	G1-R. (Optionally) Refine step G1 by adding or removing user characteristics that predict differences in performance
	N4. Measure and compare the performance of users completing the task(s) with and without the prototype user interface	E2-R. Repeat step E2 (with modified task and/or interface).	G2-R. Repeat step G2 (with modified task and/or interface).
	N5. Make changes to the prototype user interface based on the results of the comparison, and repeat the process	E3-R. Repeat step E3.	G3-R. Repeat step G3.

Table 7.2. Comparison of approaches proposed by Neuwirth et al., and Egan with the user-centric reference-task-based approach used in this thesis.

Egan's framework is general and does not prescribe how to isolate the sources of variation. Neuwirth et al.'s steps are more specific. They suggest first an observation of the current situation (step 2) and then a comparative evaluation of performance with and without the aid of the prototype user interface (step 4).

This thesis sought to combine designing for individual differences (Egan) with a design strategy that enhances interface usability for key tasks (Neuwirth et al.). Table 7.2 provides a summary and comparison of these two approaches. The table also outlines a combined approach, which aims to develop or modify the user interface to minimize the differences in performance for all users with respect to selected reference tasks (Whittaker et al., 2000).

The studies carried out in this thesis followed the steps of the user-centric reference-task-based methodology (as presented in Table 7.2) and were as follows:

G1. *Select and develop reference tasks and establish user characteristics (individual differences) that predict the biggest differences in performance*: Information finding in email inbox was selected as an important and realistic task. Based on the knowledge of the task, interface and human cognition, three candidate cognitive abilities were selected that were likely to significantly influence task performance.

G2. *Study user performance, focusing on differences between user groups at the task and user interface level*: A user study was conducted to assess the interaction between UI and Task and to isolate the sources of variation of user performance attributable to joint task/UI effects, task effects, and UI effects separately. Using a UI x Task design in the user study isolated the sources of variation in user performance.

G3. *Redesign the user interface to minimize differences between user groups across the selected tasks*: Based on the results from the first study, the interface was re-designed (1) to achieve better performance on the "Header" task, and (2) to reduce the detrimental impact of user interface and/or tasks on users low on flexibility of closure (slow on the "Date" task in the UI Text) and low on visual memory (slow on the "Header" task).

G1-R. *(Optionally) Refine step G1 by adding or removing user characteristics that predict differences in performance*: To introduce possibly different variations in performance in the follow-up study, the fourth cognitive ability (speed of closure - CS) was added along with a third task ("Mixed").

G2-R. *Repeat step G2 (with modified task and/or interface)*: To isolate the sources of variation in user performance and to examine the effects of interface re-design, the same UI x Task experimental design was used in the second user study. As a result, perhaps, of redesign and minimizing differences between the two levels of user interface, the effect of cognitive abilities on performance time was reduced.

G3-R. *Repeat step G3*: Results from the study inform the next design iteration.

7.4 Contributions

The answers to the original research questions are as follows: 1) The effects of cognitive abilities on information finding tasks in email interfaces appear to form a complex pattern; 2) More visual user interface benefits all users (in terms of performance time), but only on the "Date" task.

In reaching these answers, the research has made four types of contribution in the areas of uncovering individual differences in performance and understanding their determinants, methodology, and user interface design:

7.4.1 Effects of Cognitive Factors on Email Interaction

1. Found that different cognitive abilities affect user performance at different stages of interaction. In particular, working memory was found to affect user learning, as well as task performance, while flexibility of closure and visual memory were found to affect task performance.

2. Found multiple roles of working memory in email interaction: in learning and in task performance.

7.4.2 Determinants of Performance and Email Behaviour—User Groups

3. Identified one grouping of users, based on the observed performance and effort measures. Membership in two clusters identified in this grouping was correlated with dif-

ferences in cognitive abilities (speed of closure, visual memory, working memory) and participants' email experience.

4. Identified a second grouping, based on self-reported email behaviour. Two identified clusters corresponded to two email styles (with respect to handling prospective messages in email). Users in one cluster kept all types of email message, including both past (archived) information and future (prospective) information, while users in the other cluster did not keep messages. Differences between participants in the two clusters were correlated with cognitive ability (flexibility of closure) and with their email experience.

7.4.3 Methodological Contributions

5. Developed an instance of a combined user-centric and reference-task-based methodology. An approach that aims to develop (or modify) the user interface, minimizing differences in performance for all users with respect to selected reference tasks.

6. Developed (candidate) email reference tasks and showed the effects that different tasks have on performance. Established metrics associated with those tasks for evaluating email interfaces.

7.4.4 Design Contribution

7. Designed and evaluated an email interface that combines a text inbox with a calendar-like view of pending task attributes.

7.5 Limitations

Research contributions need to be considered in the context of limitations to their generalizability. The questions posed in this thesis were general. The goal was to uncover and understand general patterns of email users' behaviour and general principles for user interface design. The method of inquiry employed in the thesis relied on empirical studies, which were unavoidably limited by the specific ways and conditions in which they were conducted. For example, in the experimental evaluation of the WebTaskMail user interface, the research interest was in uncovering patterns of user behaviour relative to general human characteristics (cognitive abilities), and in examining the value of principles that were used in creating the interface (not just this *particular* interface, or these *specific* study participants). Thus, there is a need to generalize beyond the conditions of specific studies. In order to understand the limits of generalizability, the choices and assumptions made in the course of the research need to be made explicit. This section will review the most important points in this thesis where such choices were made. The discussion is in the spirit of the framework for epistemological analysis in human factors studies proposed by Xiao & Vicente (2000).

7.5.1 Choice of a Visual Form

The email interfaces designed as part of this thesis had the objective of making processing of pending tasks carried by email messages easier by creating a more visual representation of those tasks. A choice was made to visually represent temporal attributes of pending tasks: start- and end-dates for events, and due-dates for to-do's. Clearly, this information could be mapped onto many different forms. The chosen representation, in which time is represented as a horizontal timeline, with the time arrow running from left to right, is commonly found in Western culture and thus familiar to the study participants.

A simplifying assumption was made that one message corresponds to one task. Although both interfaces could represent multiple pending tasks associated with one message (e.g., message in the third row from the top in Figure 4.6), currently all such tasks would be displayed on one horizontal line and thus be associated with the same Subject-line (and with one message body). In the case of different (and unrelated) tasks being described by one subject line, users might be forced to get more information by opening the message. Users with low working memory and/or low visual memory might be affected by the additional operations required. However, as will be argued below, making the assumption of one task per message should not significantly lower the validity of the studies. First, based on observations of how people handle email messages, associating one task with one message may be good practice. It ensures that a specific aspect of a message will be addressed by its recipient. Second, understanding the role of cognitive abilities and interfaces in handling single-task messages is a good first step before examining multiple-task messages.

7.5.2 Choice of a User Task

The practical objective of providing a "better" support for handling prospective information in the email inbox was instantiated as providing more efficient support for information finding in prospective messages. In the field study, monitoring and retrieval of information from prospective messages were found to be important, but insufficiently supported in email. Both monitoring and retrieval require finding information in email messages. Thus, information finding was chosen as a realistic task, which is frequently performed as part of higher level activities. Three specific types of information finding task were used: "Header", "Date" and "Mixed". As discussed in Section 7.2.1, the main task effects and the interaction effects between task and user interface conditions indicated a dependency between the type of retrieval target (used to define the tasks) and the visual representation of this information. Thus, other variations of information finding tasks may be expected to yield somewhat different results and to favour different visual elements in the user interfaces.

7.5.3 Choice of Cognitive Abilities

The four cognitive abilities used in the studies were selected for the likelihood of their impact on email task performance. The results essentially confirmed the expected impact. However, the affected measures and the direction of impact were not always as foreseen. While significant effects of the chosen cognitive abilities were found, other cognitive factors may influence email task performance as well. Understanding the role of the four selected cognitive abilities in task performance on the four different email interfaces (TaskView, Outlook, WebTaskMail-Text and WebTaskMail-Visual) provides a good starting point for further research in this area.

The cognitive abilities were assessed using tests from the Kit of Factor Referenced Cognitive Tests (Ekstrom et al., 1976). These factors were identified as distinct cognitive abilities. Validity (i.e., construct validity) of the specific factors examined in this thesis is supported by their membership in a larger set of commonly agreed upon primary cognitive factors (Cattell, 1971; Carroll, 1974; 1993; Ekstrom et al, 1976). Those primary factors are listed in Appendix B. Reliability of the cognitive tests rests on many years of testing performed by their creators (Ekstrom et al., 1976).

7.5.4 Choice of Dependent Measures

TaskView and WebTaskMail email interfaces were evaluated with respect to more efficient[1] support for information finding in prospective messages. Performance time was chosen as a typical measure of efficiency. In the second study, two other interaction measures were added: amount of sorting and scrolling performed in the inbox. The dependent measures were found to interact in varying ways with different cognitive abilities, user interfaces, and tasks. In particular, working memory and flexibility of closure affected performance time, while visual memory and working memory, affected scrolling, and sorting. Including other dependent measures (e.g., mouse movement, eye fixations) would probably result in different effects. The current dependent measures were carefully chosen; adding any new measures would require a good rationale for doing so.

7.5.5 Choice of Participants

Participants in the two main studies were recruited mostly from the population of graduate students at the University of Toronto. Clearly, this is a specific user population. The population was characterized by using cognitive ability tests and a few other measures

1. Effectiveness (defined as accuracy) was also measured. However, given no time limit for task execution, no trade-off was found between accuracy and time.

(i.e., email experience). A relatively large variation in cognitive ability test results (e.g., as seen by comparing Table B.2 and Table 6.1) indicates a varied user group. It is expected that a different population characterized by the same cognitive abilities (and other measures, such as experience) will attain similar performance on the same email tasks and interfaces.

7.5.6 Choice of an Experimental Context

The two main studies were carried out as controlled laboratory studies, in which participants interacted with the prepared email messages performing tasks supplied by the experimenter. Controlled studies, rather then field studies, were carried out to be able to measure user performance on the selected task without the potentially confounding impact of uncontrollable factors found in user environments. In doing this, care was taken to create a relatively realistic user task, which maintains at least some degree of ecological validity.

The next section discusses how to move beyond some of those limitations.

Area of research	Specific item for future research
Role of cognitive abilities	Narrowing down the role of working memory in task performance
	Examining effects of working memory over longer time period - field studies
	Creation of predictive cognitive models
Methodology	Using different reference tasks
Generalizing results	Studying different population groups
	Studying other factors (e.g., organizational): field studies
	Broadening the scope - taking into account other factors
User interface design	Exploring zoomable email user interfaces
System design	Creating adaptive / adaptable systems
	Employing information extraction

Table 7.3. Directions for future research.

7.6 Future Work

This thesis' research can be extended or continued in several different directions. A few possible directions are outlined in this section. Table 7.3 provides a summary, while the details are described below.

7.6.1 Narrowing Down the Role of Cognitive Abilities in Task Performance

Further research is needed (using techniques such as eye-tracking) to disentangle email processing requirements on working memory (e.g., storage vs. attention control). The results of such research should help designers to choose an appropriate focus for refining email user interfaces (e.g., by reducing distracting information, by reducing the amount of information needed to be stored in human memory, or by improving manipulation and visualization of information; e.g., through additional interface functions to supplement the sorting and scrolling functions currently available)

Field studies may help to assess the effect of low working memory, flexibility of closure, and visual memory on email use in naturalistic contexts and over longer periods of time. Since email is becoming increasingly essential, the design of *low-cognitive-ability-friendly* (e.g., low-WM-friendly) email interfaces may be useful.

Another potentially fruitful a venue of research could the creation of predictive cognitive models, for example, using the ACT-R/PM framework (Anderson et al., 1997; Anderson et al., 2002). Such models have been successfully used in human-computer interaction to produce user models that could assess different computer interfaces (e.g., Byrne, 2001; Ehret, 2002). ACT-R was also used to model individual differences, but only to model individual differences in working memory (Daily, 2001). When complemented by a perception substrate (Amant & Riedl, 2001), these models can interact with any graphical user interface and be used to test predictions of user performance with new email interfaces.

7.6.2 Different Population Groups

Since these user studies were carried out with a mainly university sample, studies with different population groups are needed to examine whether the obtained results are generalizable.

7.6.3 Refining the Methodology

The methodology employed in the two user studies involved selecting a reference task that meets the criteria defined in the literature, that is, that the selected task is *real*, *frequent*, or *critical* (Whittaker et al, 2000). *Information finding* was chosen as a task meeting these criteria. The three variations of the *information finding* task demonstrated that a relatively small difference between the tasks can create significant differences in performance, both between different user interfaces and between different groups of users (e.g., varying by level of cognitive ability). Further research is needed to refine tasks and to select, from a potentially large variety of tasks that can be performed, those that let us discriminate performance between interfaces and, separately, those that let us discriminate between groups of users. Thus two types of *task-specificity* are proposed, *user-interface-specificity* and *user-group-specificity*. *User-interface-specificity* is useful in comparing two user interfaces. *User-group-specificity* is useful to compare the performance of two (or more) group of users on one interface. The goal, in this case, is to design a more inclusive interface, one in which performance of different population groups would be comparable. For example, in the second study, the “Mixed” task was an example of a *user-group-specific* task. It discriminated between different levels of performance for people with low and high flexibility of closure. At the same time, the “Date” task and (again) the “Mixed” task discriminated between performance in the two user interfaces used in the studies (the more visual and the textual). Thus, one task can serve both roles and be *user-interface-specific* as well as *user-group-specific*. The tasks used to discriminate can also be called *differential reference tasks*.

A more typical user interface evaluation compares two or more user interfaces with respect to performance on a given task, often with the goal of finding out if a newly designed interface is as good as existing ones. Tasks used in this type of evaluation can be called *common reference tasks*. Their specificity (i.e., their favouring one interface by design) is not desired.

The above categorization of user tasks from the two studies has been performed *a posteriori*. More research is needed to gain understanding of different tasks and to establish their taxonomy, so that tasks with desired properties can be chosen *a priori*.

7.6.4 Broadening the Scope - Taking into Account Other Factors

The study focused on individual difference in cognitive abilities and found their effects on email task performance. Further studies are needed to understand the influence on email task performance of external factors (e.g., organizational factors), other internal factors (e.g., motivation), and of their relationship to cognitive factors. How much cognitive effort are users willing to "trade" for convenience? How much cognitive effort are users willing to accept in the presence of organizational influences? Understanding email system acceptance requires knowledge of the wider context in which they are used, both internal context (e.g., cognitive abilities, motivation), as well as external factors.

7.6.5 Future User Interface Design

Another possible research avenue is to explore a wider variety of email interface designs. Such designs could take advantage of those human cognitive abilities which are under utilized in current desktop systems, for example, spatial ability. The physical environment, in which people perform everyday activities, is highly spatial and flexible. People use spatial locations to manage personal files and activities, in the physical world as well as in virtual worlds (Fitzmaurice et al., 1994; Gruen, 1996; Kirsh, 1995; Kirsh, 2001). One can expect that bringing some of these characteristics into the email environment may better support certain tasks performed in email. Zoomable user interfaces[1] are one example of interfaces that take advantage of spatial ability (Bederson et al., 1996).

The two user studies demonstrated that no interface was better overall. However, the more visual interface was better on a specific task (the "Date" task). This finding suggests building task-specific interfaces, an approach similar to the task-tailorable email interfaces suggested by Neuwirth et al. (1998). It may be impractical to build a different interface for each email task. However, in the context of personal information management in email, one might have a separate interface for managing archived information, and another for managing ephemeral and prospective information in email.

Individual differences in email performance that were found in this research indicate that different interfaces will suit different people. More research is needed to establish specific design guidelines. An intriguing possibility is offered by adaptive[2] and adaptable[3] systems (McGrenere, 2002). For example, an adaptive system could be created in which based on user interaction and minimal input from the user, the interface could be switched to one that is more "appropriate" for the user (Benyon, 1993).

7.6.6 Employing Information Extraction

This work focused on a graphical email user interface. While this work envisions a system where tasks are extracted automatically, it did not utilize such a system. Others have worked on email classification (for example, Kiritchenko et al., 2001; Mock, 2001) and explored algorithms and systems for extracting meeting information from email messages (Ge et al.; Lam et al, 2002; Stern, 2003). I expect that extraction of task information will improve in the future. As an example, I trained and used an email classification

1. A prototype zoomable email interface (called EmailLand) was created in the course of this research. However, it was an early prototype and no evaluation was performed; therefore the interface is not reported in the thesis.
2. *Adaptive systems* adapt to the user automatically, based on a user model.
3. *Adaptable systems* allow the user to change certain system parameters and adapt their behaviour accordingly.

algorithm based on Naïve Bayes (Cumming's POPFile; Cumming, 2003) to separate email messages containing events and to-do's from other email messages and spam with over 90% classification accuracy. Over a period of three months, there were 18% of such emails arriving to my email inbox. Such algorithms could be integrated into email applications to support the semi-automatic assignment of pending task attributes envisaged in this research.

7.7 Conclusions

Email has become a multi-faceted workspace for information management, including task and time management. In order to understand email and its interaction with different interface designs, tasks, and cognitive abilities, new methodologies are needed based on the concepts of reference email tasks and standardized performance and behavioural metrics. This research has identified three distinct information finding tasks ("Header", "Date", and "Mixed") that lead to different performance and behaviours under different circumstances. Furthermore, it has shown that some experimental conditions affect performance time, whereas other conditions affect behaviours such as scrolling and sorting. Over time, it should be possible to expand the set of reference email tasks used, and create a standardized set of metrics for assessing email performance and behaviour, so that more incremental progress can be made in understanding how email is used and how different interface designs affect that usage.

Email messages containing future references are handled poorly in current email systems. This research examined how external representations of task information at the user interface can improve management and awareness of pending tasks that are encoded within email messages. The present results suggest that there is considerable scope for improving email interfaces, and that detailed analysis of the effects of different interfaces on users with different levels of cognitive ability will pay dividends in terms of informing new interface designs that can benefit a wide range of users.

In view of the significant correlations observed between email experience, cognitive abilities, and user strategies, it may be difficult to identify the primary causes of email performance. As email interfaces become more sophisticated, it seems likely that more, rather than fewer, cognitive abilities will come into play. The present study showed that performance time, along with other interaction measures such as scrolling and sorting, are sensitive to differences in cognitive ability.

These results indicate that we are a long way from understanding the way in which email interfaces create loads and demands on different cognitive abilities. Such understanding is needed if more inclusive email interfaces are to be designed. While disadvantages in perception (e.g., visual) and in reading ability are well recognized, people are not usually screened for other cognitive abilities.

One interesting finding of this research was that people with low working memory also tended to report having less email experience. Email processing seems to make demands on working memory, and people with low working memory may find email processing more stressful than do people with high levels of working memory. On the basis of these results, it is suggested that the effects of working memory and of speed and flexibility of closure be examined more closely with reference to how they affect email use.

As more is learned about which cognitive abilities have the strongest effect on different types of email interface and task, it may be appropriate to develop an interface screening procedure to determine whether new email interfaces are putting people with certain combinations of cognitive ability at a selective disadvantage. One can expect that such screening would in fact be worthwhile, once there are sufficient scientific research results to justify and guide the screening process.

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Appendix A

Email as PIM

A.1 Email, Fax and Voice-mail

This appendix discusses in detail why earlier machine-mediated-communication (MMC) systems have not become personal information management (PIM) systems (it continues the discussion from Section 2.3.1 on page 17).

The two most popular (and still widely uses) MMC systems that preceded email are fax and voice mail. Those systems retained their primary function as messaging systems, though one should also note that fax evolved into a document delivery, distribution and exchange system.

The following discussion assumes a traditional view of fax and voice mail, before media and system convergence started taking place. Recently the boundaries between the different message transmission and delivery methods have began to blur, and some of the characteristics described below are now shared among email, fax and voice mail. Fax and voice messages, for example, can now be delivered in a digital format to an individual personal computer, and they can co-exist in one inbox with email messages. However, it is important to remember that, in contrast to fax and voice mail, these characteristics were present in email from the very beginning (1970s), or at least from the moment when email began to be widely used (1980s). Therefore, they served an important role in defining email use, its functions, and were influential in shaping email use as a personal information management tool. These characteristics might have also contributed to wide acceptance of email.

1. Email messages provide a permanent digital record with (a relatively) easy access to messages (issues with access to growing email inboxes are be described in Section 2.2.2 in Chapter 2).
2. Email messages can be easily converted into paper documents - email messages can thus live *both* in digital and paper (physical) world, fax only in paper (physical) world, while voice mail, depending on the implementation, in a closed world of telecommunication systems, in a separated world of an individual answering machine, or in a digital world, but without the ease of access[1].

3. Email message content can be processed easier than fax or voice message. Fax is an image, and as such it is more difficult to process[1]. Voice message is a time-based media. In a raw form it a "sound image" or a record of a voice wave form[2].
4. All three systems support access at a message level. However, access to faxes and voice mail is (typically) more difficult than to email.
5. The above technological limitation has a bearing on a possible processing of email messages. While all three systems support access at the message level, in email a finer grain access is easier to achieve (e.g., using a simple text extraction, combined with structured email header).
6. Email messages are easily portable between different systems. Faxes are portable, but it is more cumbersome to move the paper. Voice mail content is often limited to one system.
7. Email can be accessed at the same time from many places. Paper-based faxes only exist in one place, and unless a system is built where multiple human agents access the same fax storage.
8. Email can be used for transmission of wide spectrum of information types, while fax and voice mail are more limited. These different information types define how email is being used, as well as functional requirements for email programs.
9. Ubiquity of personal computers (email accounts, and mobile, email-capable devices) enables direct, personal email delivery. Email messages are delivered "directly" to the individual's personal computer. Fax, on the other hand, is often delivered to a shared fax machine. And although transmission of email messages makes them more like open postcards, and fax transmission is secure, the point of delivery makes email messages more personal and trusted[3].
10. Very low or virtually no cost associated with an email message, in particular, the cost of an email transmission does *not* depend on the geographical or network distance (for the sender and recipient).

Thus email, as used in practice, is becoming a place for personal information management.

1. Due to the nature of voice, or more generally sound, which is a time-based media, and thus requires a sequential access
1. Optical Character Recognition (OCR) technology can be used to recognize text contained in images, but the kind of technologies do not offer perfect text recognition and they add to the system complexity.
2. Speech is also difficult to process, as it requires speech-to-text technology, which is still far from accurate.
3. Of course, one cannot forget at this point, that many corporations keep a record of all email transmissions, and that email messages are the property of a corporation where one is employed.

Appendix B

Human Ability Factors

B.1 Primary Ability Factors

This appendix presents primary ability factors. The twenty factors listed in Table B.1 are commonly agreed upon as the most important in the ability sphere (Kline, 2000).

V	verbal ability: understanding words and ideas
N	numerical factor: facility in the manipulation of numbers, not arithmetic reasoning
S	spatial ability: ability to visualize figures in different orientations
P	perceptual speed and accuracy: involving rapid assessment of differences between pairs of stimuli
Cs[a]	**speed of closure: the ability to complete a pattern with parts missing**
I	inductive reasoning
Ma	rote memory: memory for pairs within which there are no mediating links
Mk	mechanical ability
Cf[a]	**flexibility of closure: ability to find stimuli embedded in distractors**
Ms[a]	**memory span: the ability immediately to recall digits or letters**
Sp	spelling
E	aesthetic judgment: the ability to detect the basic principles of good art
Mm	meaningful memory: the ability to learn links between pairs of linked stimuli
O1	originality of ideational flexibility: the ability to generate many different and original ideas
F1	ideational fluency, similar to O1 and O2: the ability to generate ideas on a topic rapidly
W	word fluency: rapid production of words conforming to letter requirements
O2	originality-, marked by the test of combining two objects into a functional object
A	aiming: hand eye coordination
Rd	representational drawing ability
Au	auditory ability: the ability to differentiate between tones and to remember a sequence of tones

Table B.1: The primary (first-order) factors of human ability.
(Kline, 2000)

a. The three visually differentiated factors (Cs, Cf, and Ms) were used in this thesis. The fourth factor used in the thesis, Visual Memory (VM), is a secondary-order factor and thus not present in this table.

B.2 Statistics on Factor-Referenced Cognitive Tests

	Cognitive ability			
	CF-2[a]	**CS-1[b]**	**MV-1[b]**	**MV-2[b]**
Mean	36.2%	76%	66.9%	45%
Std. dev.	8.9%	18%	17.8%	19.6%

Table B.2: Statistics on factor-referenced cognitive tests.
(Ekstrom et al. 1976)

a. Data on CF-2 test from 1963 Kit (11th & 12th graders).

b. Data on CS-1, MV-1, and MV-2 tests from 1976 Kit (male Naval recruits). This Kit was used in the thesis.

Appendix C

Field Study Details — Results

C.1 Questionnaire Results

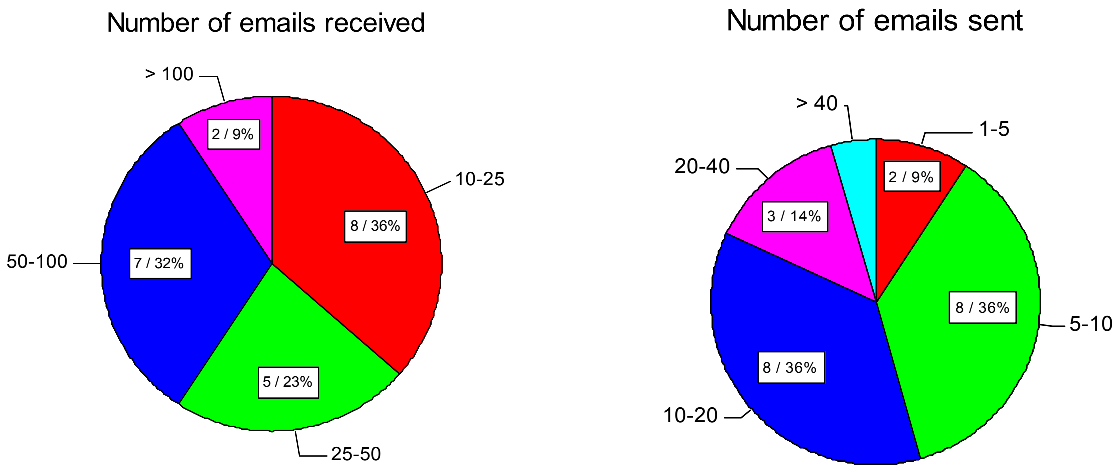


Figure C.1. Number of email messages received and send per day.

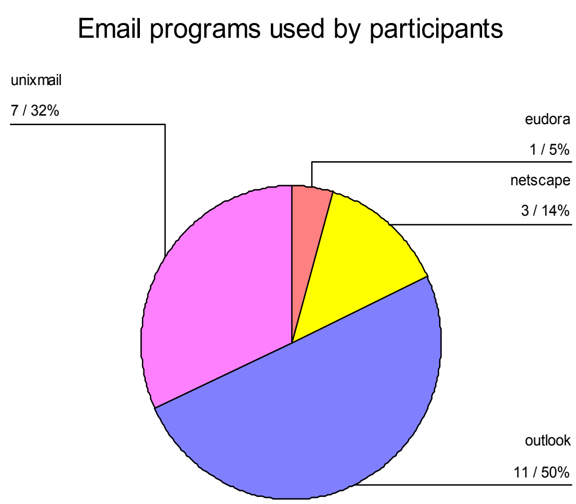


Figure C.2. Email programs used by the study participants.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	both	8	36.4	36.4	36.4
	messy	9	40.9	40.9	77.3
	neat	5	22.7	22.7	100.0
	Total	22	100.0	100.0	

Table C.1: State of the study participant's office desks.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		2	9.1	9.1	9.1
	almost_always	11	50.0	50.0	59.1
	sometimes	1	4.5	4.5	63.6
	usually	8	36.4	36.4	100.0
	Total	22	100.0	100.0	

Table C.2: Frequency of reading email all the time.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		5	22.7	22.7	22.7
	almost_always	5	22.7	22.7	45.5
	almost_never	4	18.2	18.2	63.6
	rarely	3	13.6	13.6	77.3
	sometimes	3	13.6	13.6	90.9
	usually	2	9.1	9.1	100.0
	Total	22	100.0	100.0	

Table C.3: Frequency of reading email at specific times.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		4	18.2	18.2	18.2
	almost_always	3	13.6	13.6	31.8
	almost_never	2	9.1	9.1	40.9
	sometimes	9	40.9	40.9	81.8
	usually	4	18.2	18.2	100.0
	Total	22	100.0	100.0	

Table C.4: Frequency of reading email at random times.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		3	13.6	13.6	13.6
	almost_always	3	13.6	13.6	27.3
	almost_never	2	9.1	9.1	36.4
	rarely	5	22.7	22.7	59.1
	sometimes	2	9.1	9.1	68.2
	usually	7	31.8	31.8	100.0
	Total	22	100.0	100.0	

Table C.5: Frequency of transferring future messages from email to a scheduler.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		4	18.2	18.2	18.2
	almost_always	1	4.5	4.5	22.7
	almost_never	4	18.2	18.2	40.9
	rarely	4	18.2	18.2	59.1
	sometimes	7	31.8	31.8	90.9
	usually	2	9.1	9.1	100.0
	Total	22	100.0	100.0	

Table C.6: Frequency of transferring future messages from email to a to-do list.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		1	4.5	4.5	4.5
	almost_always	6	27.3	27.3	31.8
	almost_never	2	9.1	9.1	40.9
	rarely	3	13.6	13.6	54.5
	sometimes	7	31.8	31.8	86.4
	usually	3	13.6	13.6	100.0
	Total	22	100.0	100.0	

Table C.7: Frequency of keeping future messages in email.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		5	22.7	22.7	22.7
	almost_always	2	9.1	9.1	31.8
	almost_never	7	31.8	31.8	63.6
	rarely	5	22.7	22.7	86.4
	sometimes	2	9.1	9.1	95.5
	usually	1	4.5	4.5	100.0
	Total	22	100.0	100.0	

Table C.8: Frequency of transferring future messages from email to a notebook.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		1	4.5	4.5	4.5
	almost_always	6	27.3	27.3	31.8
	almost_never	2	9.1	9.1	40.9
	rarely	1	4.5	4.5	45.5
	sometimes	4	18.2	18.2	63.6
	usually	8	36.4	36.4	100.0
	Total	22	100.0	100.0	

Table C.9: Frequency of reminding oneself by keeping messages visible.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		3	13.6	13.6	13.6
	almost_always	1	4.5	4.5	18.2
	almost_never	10	45.5	45.5	63.6
	rarely	3	13.6	13.6	77.3
	sometimes	2	9.1	9.1	86.4
	usually	3	13.6	13.6	100.0
	Total	22	100.0	100.0	

Table C.10: Frequency of using auto-reminders in email.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	almost_never	1	4.5	4.5	4.5
	rarely	3	13.6	13.6	18.2
	sometimes	13	59.1	59.1	77.3
	usually	5	22.7	22.7	100.0
	Total	22	100.0	100.0	

Table C.11: Frequency of email messages interrupting other tasks.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		2	9.1	9.1	9.1
	no	10	45.5	45.5	54.5
	sometimes	4	18.2	18.2	72.7
	yes	6	27.3	27.3	100.0
	Total	22	100.0	100.0	

Table C.12: Frequency of filing messages into folders before they are dealt with.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	afew_week	9	40.9	40.9	40.9
	less_once_week	2	9.1	9.1	50.0
	once_day	2	9.1	9.1	59.1
	once_week	7	31.8	31.8	90.9
	several_aday	2	9.1	9.1	100.0
	Total	22	100.0	100.0	

Table C.13: Frequency of accessing email specifically to look up information in messages.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		1	4.5	4.5	4.5
	always	10	45.5	45.5	50.0
	sometimes	1	4.5	4.5	54.5
	usually	10	45.5	45.5	100.0
	Total	22	100.0	100.0	

Table C.14: Frequency of feeling about email “on top”.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		8	36.4	36.4	36.4
	always	1	4.5	4.5	40.9
	never	2	9.1	9.1	50.0
	rarely	2	9.1	9.1	59.1
	sometimes	8	36.4	36.4	95.5
	usually	1	4.5	4.5	100.0
	Total	22	100.0	100.0	

Table C.15: Frequency of feeling about email “neutral”.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		4	18.2	18.2	18.2
	never	4	18.2	18.2	36.4
	rarely	7	31.8	31.8	68.2
	sometimes	5	22.7	22.7	90.9
	usually	2	9.1	9.1	100.0
	Total	22	100.0	100.0	

Table C.16: Frequency of feeling about email “overloaded”.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	10	45.5	45.5	45.5
	2	7	31.8	31.8	77.3
	3	4	18.2	18.2	95.5
	4	1	4.5	4.5	100.0
	Total	22	100.0	100.0	

Table C.17: Number of email accounts.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	no	5	22.7	22.7	22.7
	yes	17	77.3	77.3	100.0
	Total	22	100.0	100.0	

Table C.18: Does work email account receive most email messages?

C.2 Results from the Selected Analyses

C.2.1 Factor Analysis

The questionnaire and interview results were analyzed using principal component factor analysis.

Factor	Variables	FL
Prospective operations. Interpretation: Time-sensitive info is kept or transferred from email. If kept than email reminds about future events and contains both future info as well as past info. And user tend to look up info in email when not replying.	TRKEEPN Transfer time-sensitive msgs - keep	.847
	TINFKEEP Time-sensitive info kept	.821
	EMINDFUT Email reminds about future events	.813
	TINFTRAN Time-sensitive info transferred from email	-.777
	TRSCHEN Transfer time-sensitive msgs - scheduler	-.670
	TRAGRALN Transfer time-sensitive msgs - transfer grp	-.622
	INBFUTNB Inbox contents referring to future events (b)	.617
	TINFDELE Time-sensitive info deleted	-.561
	INARCHN Inbox: clean=no past, dirty=inbox incl past	.556
	LOKNREPN Looking up info not when replying	.536
	RDRELEN Reading DLs - as relevant	.469
Auto filtering. Interpretation: AF is used to sep tasks & DLs. At the same time folders contain future.	FLDRMI Folders used as multiple-inboxes (future info)	.855
	HFILAUTN Filtering automatically	.828
	FILEBEFN File before handled	.698
	FILEDLS Why file: when msg sent by a DL	.670
	FLDRFUT Folders contain future info	.628
	LOKREWEN Looking up info when replying - on web	.469
Reading DLs. Interpretation: Users either read DLs in spare time or as normal msgs. If as normal then tend to recv DLs as individual msgs.	RDLSPARN Reading DLs - in spare time	.882
	RDLNORMN Reading DLs - as normal msgs	-.778
	RDLSRCHN Reading DLs - searching stored	.471
	DLSEPMN DLs delivered as individual msgs	-.433
Source of email overload. Interpretation: Users who feel overloaded tend to send more messages and are likely to have a messy desk.	FOVERN feel about email overloaded	.923
	FONTON feel about email on top	-.868
	NSENDN NUMBER OF SEND MESSAGES	.589
	OFFICE_N OFFICE_DESK_NO	.486
Reading email. Interpretation: Users who read email all the time, let email interrupt other tasks & also read DLs.	INTERUPN Email msgs interrupt tasks	.913
	RDALLTN Email read all the time	.804
	RDRNDTN Email read at random times	-.610
	RDLNEVEN Reading DLs - almost never	-.415
Experience. Interpretation: More experienced email users tend to file manually & have less email accts.	YRS_FULL YEARS FULLTIME	.938
	YRSUSD YRS_USEDEMAIL	.849
	HFILMANN Filtering manually	.511
	NUM_EMAI NUM_EMAIL_ACCTS	-.455
Autoreminders. Interpretation: Users who use auto-reminders tends not to receive DLs as digests.	RMAUTON What reminds - auto reminders	.932
	REMAUTO Autoreminders	.867
	DLDIGEN DLs delivered as digests	-.625
Email traffic & reminders. Users who receive more emails tend to use external reminders.	NRECINT NUMBER EMIALS RECEIVED	.926
	REMEXTER External reminders (PIMs)	.593

Table C.19: Selected factors from factor analysis

(full results are included in Table C.20)

ALL3. 14-NOV-2000 19:43:58	Rotated Component Matrix	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Prospective operations. Time-sensitive info is kept or transferred from email. If kept than email reminds about future events and contains both future info as well as past info. And user tend to look up info in email when not replying.	TRKEEPN Transfer time-sensitive msgs - keep	**.847**				.191			-.229				-.153	-.160		.316
	TINFKEEP Time-sensitive info kept	**.821**	.168					-.164		-.249		.169			.255	
	EMINDFUT Email reminds about future events	**.813**		-.166		.181			.219			.387				
	TINFTRAN Time-sensitive info transferred from email	**-.777**	-.236		-.250	-.229	-.165	-.212			.199	.185				
	TRSCHEN Transfer time-sensitive msgs - scheduler	**-.670**		.213			-.172	.192			.217	.462			-.220	.150
	TRAGRALN Transfer time-sensitive msgs - transfer grpd.	**-.622**		.154	.255	-.171		.175	.350	.296	.269	.243	.260			
	INBFUTNB Inbox contents referring to future events (b)	**.617**						-.182		-.364	.169	.194	-.187	.332	-.393	.151
	TINFDELE Time-sensitive info deleted	**-.561**	-.198	-.268		.156		.244		**.420**			.331		-.151	.227
	INARCHN Inbox: clean=no past, dirty=inbox incl past	**.556**		.171	-.182	**-.475**				-.299	.206	-.270		-.298		
	LOKNREPN Looking up info not when replying	**.536**					-.225	.165		.215		.277			.518	.402
	RDRELEN Reading DLs - as relevant	**.469**		.333		-.391		-.439		**.416**	-.163			-.209		
2. **Auto filtering**. AF is used to sep tasks & DLs. At the same time folders contain future.	**FLDRMI** Folders used as multiple-inboxes (future info)		**.855**				.154				.175	.291	.169			
	HFILAUTN Filtering automatically		**.828**			-.251	-.211					-.221		.241		-.150
	FILEBEFN File before handled	.251	**.698**						.271		-.170	-.247	-.260			.295
	FILEDLS Why file: when msg sent by a DL	.398	**.670**		.152	-.257				-.296			-.163			
	FLDRFUT Folders contain future info		**.628**				.376		.184			.270	**.395**		.366	.156
	LOKREWEN Looking up info when replying - on web		**.469**	-.292		.300	-.391				-.169	-.377	-.223	.300	.266	
3. **Reading DLs**. Users either read DLs in spare time or as normal msgs. If as normal then tend to recv DLs as individual msgs.	RDLSPARN Reading DLs - in spare time	-.191		**.882**				-.185				.172		-.157		
	RDLNORMN Reading DLs - as normal msgs			**-.778**								.404				.368
	RDLSRCHN Reading DLs - searching stored			**.471**	-.267	-.161	.383	-.250		-.155			**-.434**	.419		
	DLSEPMN DLs delivered as individual msgs	**.418**	-.189	**-.433**			**-.415**		-.200	-.178	.247		.205			.354
4. Source of email overload. Users who feel overloaded tend to send more messages and are likely to have a messy desk.	FOVERN feel about email overloaded			.154	**.923**	-.180										
	FONTON feel about email on top		-.186	.189	**-.868**										-.260	
	NSENDN NUMBER OF SEND MESSAGES	.152	.171	-.271	**.589**	.332	.198		-.328				.206	.304		
	OFFICE_N OFFICE_DESK_NO	.302			**.486**			.420	-.395			-.290			.352	-.225
5. **Reading email**. Users who read email all the time, let email interrupt other tasks & also read DLs.	INTERUPN Email msgs interrupt tasks	.277				**.913**										
	RDALLTN Email read all the time	.162				**.804**			.162		.292	.200		-.247		
	RDRNDTN Email read at random times			-.198	-.470	**-.610**		-.249	.270	.170	-.240	-.178				
	RDLNEVEN Reading DLs - almost never		.358	.270	-.333	**-.415**			-.187	-.347	-.241	-.334	.195	.337		
6. **Experience**. More experienced email users tend to file manually & have less email accts.	YRS_FULL YEARS FULLTIME						**.938**				.213					
	YRSUSD YRS_USEDEMAIL			.268			**.849**	.258			-.237					
	HFILMANN Filtering manually	-.172	**-.405**	-.384		.160	**.511**	.415	.257					-.178		
	NUM_EMAI NUM_EMAIL_ACCTS	.173		**-.403**	-.232		**-.455**		**.406**	.229		.220	.279	.212	-.244	-.253
7. Basic filing. If folders exist then file for future reference. (weak) ?users tend not to look up in attch	FILEFUTR Why file: for future reference				-.353	-.158		**.837**	.207							
	FILENO Why file: never file email msgs	.156	-.200	.233	-.253		-.202	**-.816**						-.163		
	FLDRPAST Folders contain past (=exist)				.388	.209	.215	**.695**	.190	.277		.180		-.243		.166
	LOKREATN Looking up info when replying - in email attch		.270		.439			**-.445**	.375	.171				-.437		-.330
8. User who feel neutral about email tend to file work related info.	FILEWORK Why file: contains info related to work		.194					.312	**.860**		.197					
	FNEUTN feel about email neutral	.169	-.197	**.492**	.232	.156			**.627**		.196	-.228	-.164		-.172	
	NMSGSVRN	-.313	-.205						**.615**	-.216				-.189	-.395	.262
	RDSPETN Email read at special times	-.485		-.224	-.161				**.545**	.516	.292					
9.	RMVISIBN What reminds - by keeping visible	-.177					.201			**.911**						
	FILERELA Why file: to keep it with other related msgs		.530			.249	.244			**-.550**					-.282	
10. **Autoreminders**. Users who use autoreminders tends not to receive DLs as digests.	RMAUTON What reminds - auto reminders	-.182									**.932**					
	REMAUTO Autoreminders		.169						.234		**.867**			.180		
	DLDIGEN DLs delivered as digests	-.234	.156	**.519**			.294	.173		.212	**-.625**					-.208
11.	PROPIMEN PROPOR_MSGS_IMMEDIATE	.213		-.248				-.264				**.825**	.152	-.218		
	REMINBOX Inbox reminds (including flags)					.259	.278	.309				**.708**				.410
12.	**FLDRDLS** Folders used for on-going DL traffic								.159			-.155	**-.927**			
	RMRECRDN What reminds - by recording			-.158	.156		.316			.337	.413	-.228	**.655**			
	TRTODON Transfer time-sensitive msgs - to-do		-.228		.269	-.261			.323	.280			**.621**	-.177	.237	
	DLWEBN DLs accessed on web			.339	.161	-.334	.215		.371	.351			**-.524**			
13. **Email traffic & reminders**. Users who receive more emails tend to use external reminders.	NRECINT NUMBER EMIALS RECEIVED	.150												**.926**	-.189	
	REMEXTER External reminders (PIMs)	-.220		-.293							.278	-.397		**.593**	-.341	-.212
14.	LOKREMSN Looking up info when replying - in past emails	.171									-.188			-.210	**.894**	

Table C.20: Full results (all items) from factor analysis - Rotated component matrix.
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. Rotation converged in 84 iterations.

Selected Additional Statistics For the Factor Analysis.

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8.835	15.232	15.232	8.835	15.232	15.232	6.693	11.539	11.539
2	6.883	11.867	27.099	6.883	11.867	27.099	4.439	7.654	19.193
3	5.356	9.235	36.334	5.356	9.235	36.334	3.992	6.883	26.076
4	4.876	8.406	44.740	4.876	8.406	44.740	3.920	6.758	32.834
5	4.582	7.900	52.640	4.582	7.900	52.640	3.731	6.433	39.267
6	3.978	6.859	59.499	3.978	6.859	59.499	3.708	6.393	45.661
7	3.572	6.159	65.658	3.572	6.159	65.658	3.691	6.363	52.024
8	3.297	5.684	71.343	3.297	5.684	71.343	3.563	6.142	58.166
9	2.862	4.934	76.276	2.862	4.934	76.276	3.526	6.080	64.246
10	2.587	4.460	80.737	2.587	4.460	80.737	3.455	5.956	70.202
11	2.238	3.858	84.595	2.238	3.858	84.595	3.446	5.941	76.143
12	2.127	3.668	88.263	2.127	3.668	88.263	3.237	5.581	81.724
13	1.846	3.183	91.446	1.846	3.183	91.446	2.901	5.001	86.725
14	1.399	2.412	93.858	1.399	2.412	93.858	2.797	4.822	91.548
15	1.147	1.978	95.836	1.147	1.978	95.836	2.487	4.288	95.836
16	.954	1.644	97.480						

Table C.21: Total variance explained - factor analysis.
(Extraction Method: Principal Component Analysis)

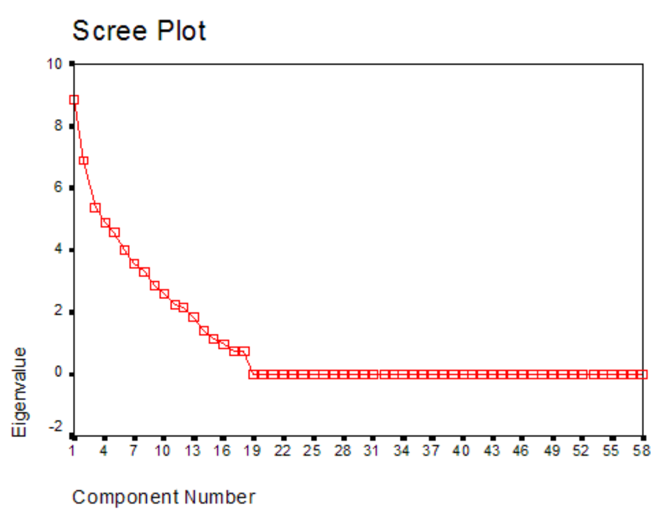


Figure C.3. Scree plot for factor analysis.

C.2.2 Cluster Analysis

ANOVA						
	Cluster		Error		F	Sig.
	Mean Square	df	Mean Square	df		
ZTRSCHEN Zscore: Transfer time-sensitive msgs -	7.804	1	0.701	17	11.128	0.004
ZTRAGRAL Zscore: Transfer time-sensitive msgs -	12.104	1	0.494	17	24.521	0.000
ZTRKEEPN Zscore: Transfer time-sensitive msgs -	9.313	1	0.667	17	13.969	0.002
ZLOKNREP Zscore: Looking up info not when replyi	1.592	1	1.029	17	1.548	0.230
ZINARCHN Zscore: Inbox: clean=no past, dirty=inb	5.919	1	0.730	17	8.105	0.011
ZINBFUTN Zscore: Inbox contents referring to fut	9.167	1	0.559	17	16.404	0.001
ZTINFTRA Zscore: Time-sensitive info transferred	7.636	1	0.610	17	12.526	0.003
ZTINFKEE Zscore: Time-sensitive info kept	14.438	1	0.210	17	68.895	0.000
ZTINFDEL Zscore: Time-sensitive info deleted	11.066	1	0.408	17	27.133	0.000
ZEMINDFU Zscore: Email reminds about future even	8.192	1	0.577	17	14.198	0.002

Table C.22: Cluster analysis - ANOVA test for significant differences between clusters.

C.2.3 Nonparametric Associations

This section presents selected significant nonparametric associations between measures obtained from questionnaires and interviews.

Directional Measures

			Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Somers' d	Symmetric	.532	.158	3.382	.001
		LOKNREPN Looking up info not when replying Dependent	.511	.150	3.382	.001
		TRKEEPN Transfer time-sensitive msgs - keep Dependent	.556	.171	3.382	.001

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Table C.23: Somers' d for LOKNREPN (looking up info in email not when replying) and TRKEEPN (prospective information is kept).

Directional Measures

			Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Somers' d	Symmetric	-.485	.150	-3.013	.003
		OFFICE_N OFFICE_DESK_NO Dependent	-.583	.179	-3.013	.003
		TINFTRAN Time-sensitive info transferred from email Dependent	-.415	.136	-3.013	.003

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Table C.24: Somers' d for OFFICE_DESK (neatness of office desk) and TINFTRAN (prospective information is transferred from email).

Directional Measures

			Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Nominal by Nominal	Lambda	Symmetric	.333	.281	1.027	.304
		INARCHN Inbox: clean=no past, dirty=inbox incl past Dependent	.375	.261	1.174	.240
		TINFKEEP Time-sensitive info kept Dependent	.286	.341	.717	.474
	Goodman and Kruskal tau	INARCHN Inbox: clean=no past, dirty=inbox incl past Dependent	.206	.187		.054[c]
		TINFKEEP Time-sensitive info kept Dependent	.206	.188		.054[c]
Ordinal by Ordinal	Somers' d	Symmetric	.453	.208	2.116	.034
		INARCHN Inbox: clean=no past, dirty=inbox incl past Dependent	.464	.212	2.116	.034
		TINFKEEP Time-sensitive info kept Dependent	.443	.207	2.116	.034

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on chi-square approximation

Table C.25: Somers' d for INARCHN (inbox contains past information) and TINFKEEP (prospective information is kept in email).

Directional Measures

			Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Nominal by Nominal	Lambda	Symmetric	.500	.242	1.612	.107
		INARCHN Inbox: clean=no past, dirty=inbox incl past Dependent	.500	.250	1.495	.135
		TINFDELE Time-sensitive info deleted Dependent	.500	.250	1.495	.135
	Goodman and Kruskal tau	INARCHN Inbox: clean=no past, dirty=inbox incl past Dependent	.323	.217		.016[c]
		TINFDELE Time-sensitive info deleted Dependent	.323	.217		.016[c]
Ordinal by Ordinal	Somers' d	Symmetric	-.568	.191	-2.888	.004
		INARCHN Inbox: clean=no past, dirty=inbox incl past Dependent	-.568	.192	-2.888	.004
		TINFDELE Time-sensitive info deleted Dependent	-.568	.192	-2.888	.004

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

c. Based on chi-square approximation

Table C.26: Somers' d for INARCHN (inbox contains past information) and TINFDELE (prospective information is deleted from email).

Directional Measures

			Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Somers' d	Symmetric	-.452	.166	-2.608	.009
		RDSPETN Email read at special times Dependent	-.595	.216	-2.608	.009
		TINFKEEP Time-sensitive info kept Dependent	-.365	.139	-2.608	.009

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Table C.27: Somers' d for RDSPETN (email is read at specific time) and TINFKEEP (prospective information is kept in email).

Directional Measures

			Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Somers' d	Symmetric	-.454	.132	-2.814	.005
		RDSPETN Email read at special times Dependent	-.671	.172	-2.814	.005
		INBFUTNB Inbox contents referring to future events (binary) Dependent	-.343	.124	-2.814	.005

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Table C.28: Somers' d for RDSPETN (email is read at specific time) and INBFUTNB (messages with future are in inbox).

Directional Measures

			Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Somers' d	Symmetric	.396	.181	2.050	.040
		DLSEPMN DLs delivered as individual msgs Dependent	.500	.226	2.050	.040
		EMINDACT Email reminds about to-dos (non-email) Dependent	.328	.157	2.050	.040

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Table C.29: Somers' d for DLSEPMN (distribution lists are received as individual messages) and EMINDACT (email reminds about future actions).

Directional Measures

			Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Ordinal by Ordinal	Somers' d	Symmetric	.431	.122	2.522	.012
		RDLNORMN Reading DLs - as normal msgs Dependent	.733	.166	2.522	.012
		EMINDEXT Email reminds about external (to-do or event) Dependent	.306	.121	2.522	.012

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Table C.30: Somers' d for RDLNORMN (distribution lists are read as regular messages) and EMINDEXT (email reminds about external future actions).

Appendix D

User Studies—Email Corpus

D.1 Email Message Corpus.

MSGID:	1			
Sender:	Kia			
Subject:	Book Club Meeting			
Start Date:	June 15, 2003	**Start Time:**	15:00	**Event**
Due Date:	June 15, 2003	**Due Time:**	17:00	

Message Body: Book Club Meeting

I would like to convene the Book Club on Sunday at 3pm in two weeks at the usual place, I hope everyone will forgive the rather large gap between meetings.

See you soon,
-- Kia

MSGID:	2			
Sender:	TechMusic			
Subject:	checking quality			
Start Date:		**Start Time:**		**To Do**
Due Date:	June 17, 2003	**Due Time:**	17:00	

Message Body: Hello !

I just wanted to check to see if the Photo CD we delivered to you was satisfactory. Please let me know by email how was the quality of the CD.

If I can be of any technical assistance please do not hesitate to email or call me.

Sincrely,
- Tech Director of services

MSGID:	3			
Sender:	Gene			
Subject:	Confirmation of meetings - interviews			
Start Date:	June 17, 2003	**Start Time:**	14:00	**Event**
Due Date:	June 417 2003	**Due Time:**	15:00	

Message Body: Here is the schedule for the Tuesday in two weeks that we just have discussed:

You will be interviewing:
John Doe from 2:00 - 3:00 pm

Yours,
- Gene

MSGID:	4			
Sender:	Library			
Subject:	Confirmation and library due date			
Start Date:		**Start Time:**		**To Do**
Due Date:	June 27, 2003	**Due Time:**	17:00	

Message Body: This is an automated confirmation that you have borrowed the following item from the library.

Title: PC Magazine Volume: 18 Issue: 9
Date Out: Today
Due Date: Four weeks from today

Please do your part by returning or renewing borrowed items on time.

Thank You
The Librarian

MSGID:	5			
Sender:	Hew			
Subject:	co-operation			
Start Date:		**Start Time:**		**To Do**
Due Date:	June 9, 2003	**Due Time:**	17:00	

Message Body: Hi there!

How are you?

My colleague is now in Toronto again. I asked him to contact you and find out if there is any kind of co-operation possible between our organizations. I learned that your company has a new president who has globalization policy.
Best regards,
- Hew

MSGID:	6			
Sender:	Friend			
Subject:	digital camera?			
Start Date:		**Start Time:**		**To Do**
Due Date:	June 3, 2003	**Due Time:**	17:00	

Message Body: Hi !

I need to take a couple of pictures of my car for insurance purposes.
Do you still have the digital camera from work? Could I borrow it soon for a few days?

Thanks,
- Me

MSGID:	7			
Sender:	Miro			
Subject:	Don's visit and seminar			
Start Date:	June 17, 2003	**Start Time:**	10:00	**Event**
Due Date:	June 17, 2003	**Due Time:**	12:00	

Message Body:

Don will be back in town on at the end of February.
He will be giving a seminar on June 17 at 10am.

Please read and summarize his latest publications before the seminar.

Miro

MSGID:	8			
Sender:	Stu			
Subject:	Email			
Start Date:		**Start Time:**		**To Do**
Due Date:	June 6, 2003	**Due Time:**	17:00	

Message Body:

Hi !

How are things going with you? I hope your weekend went well.

It has been a few days and I have not yet received your promised email. I just wanted to remind you in case you have forgotten. ;-)

Thanks,
- Stu

MSGID:	9			
Sender:	Vicky			
Subject:	Exam Booklets			
Start Date:		**Start Time:**		**To Do**
Due Date:	June 10, 2003	**Due Time:**	17:00	

Message Body:

I will have the booklets ready for you in my office next Tuesday.
We close at 5:00 p.m. at night. Do you have a key to get into
that office or will you pick them up?

Thanks!

MSGID: 10
Sender: Rosa
Subject: Formal review of the Documentation Addendum
Start Date: June 03, 2003 **Start Time:** 9:00 **Event**
Due Date: June 03, 2003 **Due Time:** 10:00
Message Body: Attached is the latest version of the Documentation Addendum. Please review before the formal review planned tomorrow from 9am-10am in the Main Room.

Not all of the document is being reviewed as some of it is being tested.

Please review sections 1-3 (How to used this guide, Installation Guide and Administrator's Guide). Appendix B is planned to be tested.

MSGID: 11
Sender: Meme
Subject: guest lecture?
Start Date: June 17, 2003 **Start Time:** 16:00 **Event**
Due Date: June 17, 2003 **Due Time:** 17:00
Message Body: Hi !

Could you do a guest lecture on New Technologies? either from 4-5 on Tue in two weeks or 3-5pm on Thu in three weeks?

If you could let me know asap a) if you can do this and b) which time, that would be grand.

Thanks,
-- meme

MSGID: 12
Sender: Colleague
Subject: Hi --- (we need some participants)
Start Date: June 11, 2003 **Start Time:** 12:00 **Event**
Due Date: June 11, 2003 **Due Time:** 13:00
Message Body: Hi !!!

We're doing a little study over here about perception of web pages and need a few more participants. Are any of your co-workers free for an hour next week? See message below. Can you pass it on with a wee bit of arm twisting?

Thanks! - Colleague from work

------- Forwarded message follows -------
We really need a little help with our research study on Web search tools.We need volunteers to help complete a study on assessing outputs from Websearch tools. Participants must be familiar with Web browsers and have some interest in movies (the subject of this portion of the study). About 45 minutes of your time is all that is required.
Would a $10 honorarium help a little?

Please come to Fourth Floor, Our Building on June 11th any time between noon and 1 pm.

To participate, please reply to this email to confirm your participation. Many thanks!

MSGID:	13			
Sender:	Dee			
Subject:	invitation to lunch			
Start Date:	June 6, 2003	**Start Time:**	13:00	**Event**
Due Date:	June 6, 2003	**Due Time:**	14:00	

Message Body:

You are invited to lunch on Friday at 1pm with a candidate for the managerial position.

I know you're very busy, but if you can come this Friday, you can help us hire the right person.

R.S.V.P.
Dee

MSGID:	14			
Sender:	John			
Subject:	Draft paper			
Start Date:		**Start Time:**		**To Do**
Due Date:	June 13, 2003	**Due Time:**	17:00	

Message Body:

Can you review this document and pass it off to Hiro within the next two weeks?

Thanks!
John

<doc content>

MSGID:	15			
Sender:	Joe			
Subject:	lost file			
Start Date:		**Start Time:**		**To Do**
Due Date:	June 20, 2003	**Due Time:**	17:00	

Message Body:

some time ago you put me in touch with a friend of yours, then in France,
who gave me a book. Unfortunately, as a result of a system crash
I lost all his correspondence, and even his name. I still
have the book and would like to send it back.

Do you remember? Please let me know.

Best,
Joe

MSGID:	16			
Sender:	Larry			
Subject:	Pioneer VCR			
Start Date:		**Start Time:**		**To Do**
Due Date:	June 6, 2003	**Due Time:**	17:00	

Message Body: Hi !

Listed below are the VCRs that you were looking for.
Please let me know your choice.

Larry

Pioneer VC-1XL $239 OR Sony Compact 200 $300

MSGID:	17			
Sender:	Shawn			
Subject:	meeting this week			
Start Date:	June 10, 2003	**Start Time:**	15:00	**Event**
Due Date:	June 10, 2003	**Due Time:**	16:30	

Message Body: After a longer break, we'll be meeting at the usual time and place next week (Tuesday 3pm). We should talk about the upcoming projects, but I believe that people were planning an additional topic. If so please send out an explanatory message to the group before the next meeting, thanks.

- Shawn

MSGID:	18			
Sender:	JJ			
Subject:	Meeting to discuss technology			
Start Date:	June 12, 2003	**Start Time:**	15:00	**Event**
Due Date:	June 12, 2003	**Due Time:**	16:00	

Message Body: How about meeting 3:00-4:30 on June 12?
Please check the schedule and confirm by email.

Best,
- JJ.

MSGID: 19

Sender: Lenny

Subject: Meeting?

Start Date: June 09, 2003 **Start Time:** 18:00 **Event**

Due Date: June 09, 2003 **Due Time:** 19:00

Message Body: Greetings !

Would it be possible for us to meet with you next week on Monday at 6pm to talk about our business? We could use your input on our strategies...
We have targeted two market niches (graphic design and health-care) and
there June be a need for us to work with an expert like you.
I hope you can come. This is really informal, and drinks will be on us!!

Please confirm by email. Best,
- L.

MSGID: 20

Sender: Tech Support

Subject: Need some info on your PC

Start Date: **Start Time:** **To Do**

Due Date: June 06, 2003 **Due Time:** 17:00

Message Body: Remember 2 months ago I asked you about the configuration of your PC
I am listing down the parameters I need, will you please find out the
answers for me before the end of this week? Thank you very much.

- Your Tech Support

MSGID: 21

Sender: Hana

Subject: Brochure

Start Date: **Start Time:** **To Do**

Due Date: June 10, 2003 **Due Time:** 17:00

Message Body: All -

Thanks to Jamie who responded right away to my first
request for input on our brochure layout/content.

Mark: (=You) Please provide appropriate text for the first page before the end of the week.
The current text is outdated.

Regards
- Hana

MSGID:	22			
Sender:	The Social Group			
Subject:	party !!!			
Start Date:	June 21, 2003	**Start Time:**	20:00	**Event**
Due Date:	June 21, 2003	**Due Time:**	23:30	

Message Body:

Mark your calendars for the party!
June 21, 2003 at 8pm

It will be held at the BEST bar & pub!
There will be finger foods and a cash bar.

See you there!

MSGID:	23			
Sender:	Coach			
Subject:	Volleyball games schedule			
Start Date:	June 11, 2003	**Start Time:**	18:00	**Event**
Due Date:	June 24, 2003	**Due Time:**	19:00	

Message Body:

Hi all,
I did not hear about any conflicts so far.
The playoff schedule is below
Please let me know ASAP if you have a conflict - there may
be some small chance that we can change a time slot.
Thanks,
- Your coach.

Schedule :
June 11, 6:00 - 7:00:   Volleyball team 1 & 2
June 12, 6:00 - 7:00:   Volleyball team 3 & 4
June 15, 6:00 - 8:00:   *** semi-final ***
June 24, 8:00 - 11:00:   *** final ***

MSGID:	24			
Sender:	Tim			
Subject:	Project info			
Start Date:		**Start Time:**		**To Do**
Due Date:	June 16, 2003	**Due Time:**	17:00	

Message Body:

Hello !

We met today to discuss the possibility of doing a new project, and so far we haven't made a decision, but we have generated a lot more questions.
Can you please contact the manufacturer you dealt with before and find out:
1. if their service is available in: - Canada,   - USA,   - world wide
2. how much their service costs.
Also -- could you make inquiries in the usual places about the costs for traditional type systems?
We would need to have all this information before the next week.

Buy for now,
Tim

MSGID:	25			
Sender:	Director			
Subject:	project strategies			
Start Date:	June 03, 2003	**Start Time:**	10:00	**Event**
Due Date:	June 03, 2003	**Due Time:**	12:00	
Message Body:	All,			

As agreed, we will be meeting tomorrow at 10am to talk about strategies for the next projects.
Please come with a list of ideas for the new strategies.

See you then!

MSGID:	26			
Sender:	John			
Subject:	RE: Deposit for the Trip			
Start Date:		**Start Time:**		**To Do**
Due Date:	June 19, 2003	**Due Time:**	17:00	
Message Body:	Hi, If you have not already, please make arrangements with the agent bellow.			

The are booking rooms and cannot make bookings without the deposit. Also, it
will help us determine how many people we have to expect for the reception.
Please try to make arrangements with the agent before the end of next week.

Thanks. Email me if you have any questions.
- John

MSGID:	27			
Sender:	Jay			
Subject:	re-confirmation of talk			
Start Date:	June 25, 2003	**Start Time:**	19:00	**Event**
Due Date:	June 25, 2003	**Due Time:**	21:00	
Message Body:	Hi all!			

This is to confirm that you are registered for our June 25
Financial talk, which will start at 7pm.
Please remember to pay for the registration BEFORE going to the talk (you can use your
credit card). There are no facilities to process payments immediately before the talk.

Thanks,
The Coordinator

MSGID:	28			
Sender:	Ben			
Subject:	refund			
Start Date:		**Start Time:**		**To Do**
Due Date:	June 19, 2003	**Due Time:**	15:00	

Message Body: Hi !

Please complete an appropriate form at our office.
The form should be signed by you and should be returned
to our office before June 19th.

You will get refund after submitting the form.
Ben

MSGID:	29			
Sender:	Association			
Subject:	Memberships - now renew Online!			
Start Date:		**Start Time:**		**To Do**
Due Date:	June 27, 2003	**Due Time:**	17:00	

Message Body: Your membership in The Professional Association is about to expire end of the next month, and you can now renew electronically! Please do so soon.

Thank you!

MSGID:	30			
Sender:	Kate			
Subject:	report for you review			
Start Date:		**Start Time:**		**To Do**
Due Date:	June 20, 2003	**Due Time:**	17:00	

Message Body: The report is in the mail. You will receive it soon.
Please review it and respond in three weeks at the latest.

Kate

MSGID: 31

Sender: Editor

Subject: Request for a short report

Start Date: **Start Time:** **To Do**

Due Date: June 25, 2003 **Due Time:** 17:00

Message Body: Could I ask you a favour?

Would you prepare a very short paragraph about the upcoming events. We want to publish it in the upcoming issue of the magazine
(before the end of this month approximately).

The Editor

MSGID: 32

Sender: Work Colleague

Subject: revised abstract for my seminar

Start Date: June 19, 2003 **Start Time:** 12:00 **Event**

Due Date: June 19, 2003 **Due Time:** 13:00

Message Body:
>the seminar is at noon on Thursday in two weeks. Please send the title and
>abstract for the seminar

Below is slightly modified abstract. I bolded the modified phrases. I am
still using most of the title, as I didn't find a more compact way to express the same.

I'd appreciate your comments and I'd appreciate if you find time to come to my seminar.
- Your Colleague

```
<Title: ....>
<Abstract: ....>
```

MSGID: 33

Sender: Alex

Subject: Saturday

Start Date: June 07, 2003 **Start Time:** 17:00 **Event**

Due Date: June 07, 2003 **Due Time:** 21:00

Message Body: Hey !

I just wanted to remind you of this coming Saturday at 5pm we will have a barbecue dinner here and perhaps go out somewhere afterwards. Please fill free to bring a salad, or something similar.

And you are welcome to bring someone.

See you soon!
- Alex

MSGID:	34			
Sender:	Mia			
Subject:	Dinner - see you soon!			
Start Date:	June 05, 2003	**Start Time:**	20:00	**Event**
Due Date:	June 05, 2003	**Due Time:**	22:00	

Message Body: Thursday night dinner it is, 8pm. That will actually be perfect because I have an interesting guest from China right now.

See you soon ,
Mia

MSGID:	35			
Sender:	Management			
Subject:	Seminar Today			
Start Date:	June 02, 2003	**Start Time:**	14:00	**Event**
Due Date:	June 02, 2003	**Due Time:**	15:00	

Message Body: Hello Everyone,

This is a reminder of today's seminar. Our visitor will give a presentation about his product, from 2:00 - 3:00 pm. All the staff is welcome.

Free Coffee and cookies to be served before the seminar.

See you then

MSGID:	36			
Sender:	Heather			
Subject:	Send your Ideas!			
Start Date:		**Start Time:**		**To Do**
Due Date:	June 14, 2003	**Due Time:**	17:00	

Message Body: Hello, everyone.

I have decided to conduct a social experiment by inviting you to email me ideas for our next social gathering. Please feel free to come up with ideas for fancy food, how to dress, or anything else.

Hope to hear from you all!
- Heather -

MSGID:	37			
Sender:	Chris			
Subject:	Status reports for week-ending Fri			
Start Date:		**Start Time:**		**To Do**
Due Date:	June 02, 2003	**Due Time:**	17:00	
Message Body:	I have received only 1 status report for the past week! Please submit your status reports to me, if you have not done so yet. Thanks Chris			

MSGID:	38			
Sender:	Luke			
Subject:	study			
Start Date:	June 10, 2003	**Start Time:**	13:00	**Event**
Due Date:	June 10, 2003	**Due Time:**	14:00	
Message Body:	Hi ! I am free next Tuesday from about 11-12, then 1-3. Let me know what's best. Luke.			

MSGID:	39			
Sender:	Andy			
Subject:	Thank You!			
Start Date:	June 18, 2003	**Start Time:**	19:00	**Event**
Due Date:	June 18, 2003	**Due Time:**	21:00	
Message Body:	Hi, Perhaps I should have checked my calendar first. It so happens that I'm busy every night this month. So, how about next month? If it is too early to set a dinner date now, could you email me when you will know the next month's schedule? Thanks. Talk to you soon, Andy			

MSGID: 40
Sender: Miro
Subject: This week's meeting
Start Date: June 06, 2003 **Start Time:** 14:30 **Event**
Due Date: June 06, 2003 **Due Time:** 16:00
Message Body: We need to meet this week on Friday at 2:30pm. We will have non-threatening updates on where people are in their current projects. Please come prepared with a couple of slides. Thanks.

Miro

MSGID: 41
Sender: Mico
Subject: Visit to the Computer company???
Start Date: June 16, 2003 **Start Time:** 10:00 **Event**
Due Date: June 16, 2003 **Due Time:** 13:00
Message Body: You all indicated an interest in visiting the Computer company, but none of you replied to my post. We need to tell the company how many people are going so they can plan for lunch. Please let me know by the end of the week (email)

The details: We'll be at the company from roughly 10:00 to 1:00 on Monday.

Thanks - Mico

MSGID: 42
Sender: Teddy
Subject: volunteer ?
Start Date: June 26, 2003 **Start Time:** 18:00 **Event**
Due Date: June 26, 2003 **Due Time:** 19:30
Message Body: Hi !

You mentioned you were interested in possibly volunteering with the Professional Association.

Our next executive meeting is at 6:00pm on Thursday in June 26 (pizza provided) ;-)

Please join us if still interested.

Teddy

MSGID:	43			
Sender:	Sara			
Subject:	Your order			
Start Date:		**Start Time:**		**To Do**
Due Date:	June 05, 2003	**Due Time:**	17:00	
Message Body:	Hi,			

I just looked up your account in our system and your company does not have credit terms with us. In order to ship this order, I will need either a credit application or a credit card in US funds. Can you get back to me on this issue? In the meantime, I will hold the product.

- Sara

MSGID:	44			
Sender:	Special Interest Group mailing list			
Subject:	Panel Session Announcement			
Start Date:	June 19, 2003	**Start Time:**	16:00	**Event**
Due Date:	June 19, 2003	**Due Time:**	18:00	
Message Body:				

The Special Interest Group at the University of Toronto is pleased to announce the next Panel Session honouring our heritage. We invited many interesting guests! The session will be held in the Main Building Auditorium on June 19, 2003 from 4:00-6:00 PM. A coffee hour will be held from 3:00-4:00 PM You are welcome to attend these session.

Please RSVP.

Appendix E

TaskView User Study Details

E.1 Multiple-choice Questions

Q No	Question text	Task
1	Who has requested from you text for the brochure before the end of the week (Feb 22)?	H
2	Do you have any visits outside your school/workplace scheduled for the next week (Feb25-Mar1)?	H
3	What day of the next week (Feb25-Mar1) do you have scheduled a visit outside your school/workplace?	H
4	What time is the group meeting next Tuesday (Feb 26)?	H
5	Is the meeting next Monday (Feb 25) in the afternoon or in the morning?	H
6	What day is the meeting to discuss technology scheduled for?	H
7	When is the Book Club Meeting scheduled?	H
8	How many people will be attending the meeting on Tuesday Feb 26th?	H
9	What is the meeting on Feb 25 about?	H
10	Who is giving the seminar on Feb 28?	H
11	Have you been invited to any parties in the next four weeks (till Mar10)?	H
12	What was requested from you by Chris?	H
13	Who asked that you do a guest lecture on New Technologies?	H
14	When are you going to give your guest lecture?	H
15	What do you need to do for the brochure?	H
16	When is the SIGs Panel Session?	H
17	What kind of sports games do you have scheduled?	H
18	When do you have scheduled a sports game?	H
19	What membership do you need to renew?	H
20	Can one renew the membership in your Professional Association electronically?	H
21	Do you have any tasks scheduled for the coming Saturday (Feb 23)?	D
22	At what time do you have tasks scheduled for the coming Saturday (Feb 23)?	D
23	Do you have more tasks scheduled for the next week (Feb25-Mar1) than for this week (Feb18-22)?	D
24	Do you already have any tasks scheduled for the next month (March)?	D
25	Do you have any dinners scheduled for the next two weeks (till Mar3)?	D
26	Do you have any days this week (Feb18-24) without any tasks scheduled?	D
27	Do you have any working days next week (Feb25-Mar1) without any tasks scheduled?	D
28	When does the next event take place?	D
29	How many things do you have scheduled for tomorrow (Feb 19)?	D
30	How many things do you have scheduled for today (Feb 18)?	D
31	How many events do you have to attend on Friday February 22?	D
32	What is the first day without any tasks scheduled?	D
33	Do you have any work-days in February without any tasks scheduled?	D
34	Do you have any tasks to do next Wednesday (Feb 27) in the afternoon?	D
35	How many tasks do you have scheduled for four working days (Feb25-Feb28)?	D
36	Do you have any things planned for April?	D
37	Can you schedule lunch on Tuesday Feb 26 at 12:30pm?	D
38	Do you have any coming weekends in February with nothing planned?	D
39	For how many weekends in March do you have anything planned?	D
40	Can you schedule more events on February 26?	D
41	Can you schedule anything on Tue Feb 26 at 3pm?	D
42	A friend calls you to set a dinner date for the this Thu Feb 21 or Fri Feb 22. Are you free for dinner on Thu or Fri?	D
43	Can you schedule more things on March 11 in the afternoon?	D

Appendix F

WebTaskMail User Study Details

F.1 Multiple-choice Questions

Q#	Question Text	Task
1	**Do you have any events scheduled for the coming Saturday?**	D
2	Do you already have anything scheduled for the next two weeks (June 2-15)?	D
3	Do you have any days this week (June 2-8) without anything scheduled?	D
4	Do you have any working days next week (June 9-13) without anything scheduled?	D
5	**How many events do you have to attend on Friday June 20?**	D
6	What is the first day without any events scheduled?	D
7	Do you have any work-days in June without anything scheduled?	D
8	Do you have anything to do or events to attend a week Wednesday (i.e. on Wed June 11)?	D
9	**Do you have any things planned for Sun June 22?**	D
10	Do you have any two work-days in a row with nothing scheduled?	D
11	Can you schedule a morning meeting (9am-11am) on Thu June 26?	D
12	A friend calls you to set a dinner date for Tue June 24. Are you free for dinner on that date?	D
13	Can you schedule more things on Mon June 23?	D
14	**When does the next seminar take place?**	M
15	**How many meetings do you have scheduled for tomorrow (June 3)?**	M
16	Who has requested from you text for the brochure during the next week (June 9-15) ?	M
17	Do you have any outside visits/trips scheduled for the followings weeks?	M
18	What day of the week two weeks from now (June 16-22) do you have scheduled an outside visit?	M
19	Is the meeting a week Monday (June 9) in the morning or in the evening?	M
20	**What day is the meeting to discuss technology scheduled for?**	M
21	Do you have any parties to go to in the coming weekends in June?	M
22	How many people will be attending the group meeting on Tuesday June 10th?	M
23	What is the meeting on Mon June 9 about?	M
24	Who is giving the seminar on June 17?	M
25	Have you been invited to any parties this month?	H
26	What do you need to pick up from Vicky?	H
27	What was requested from you by Chris?	H
28	Who asked that you do a guest lecture?	H
29	What do you need to do for the brochure?	H
30	When is the SIGs Panel Session?	H
31	What kind of sports game do you have scheduled?	H
32	Can one renew the membership in your Association on-line?	H
33	Are there any things to do related to a library?	H
34	Who announced the next Book Club Meeting?	H
35	Whom are you meeting for dinner?	H
36	Who asked you to send ideas for a social event?	H

F.2 Web Survey — Demographics and Email Use Questions

Demographics and Email Survey

The purpose of this short questionnaire is to gain basic information about you and your email handling practices. There are no "right" or "wrong" answers. The questionnaire should take about 5-8 minutes. If you have more than one email account, please answer the questions considering **all** of your email accounts together. If you have any questions, please ask the experimenter by email (study2@emailresearch.org)

Fields marked with * are required.
Note: Please use **the same email address**, that you used before to communicate with the experimenter. This email address is your user id, and the data from the questionnaire will not be saved if you use a different email address.

First and last name * [ ]

E-mail address * [ ] (the **same** address that you used before)

School, University, Company, etc [ ]

Department, division, etc [ ]

Lab, Group, etc [ ]

Degree Program or Position [ ]

Your main role ○ Student ○ Educator ○ Technician ○ Researcher ○ Designer ○ Sales ○ Manager ○ Administrator ○ Executive

1. If you are currently working full-time, how many years have you been working full-time (in total)?
please specify [ ] years

2. If you are currently full-time in a graduate school, how many years have you been in the graduate school (in total)?
please specify [ ] years

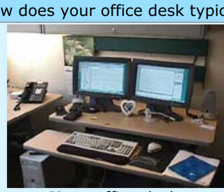
3. If you are currently a full-time undergraduate student, what year have you finished this spring?
please specify [ ] years

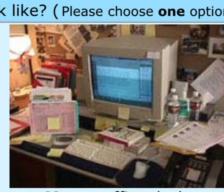
4. If you are currently studying but you worked full-time before, how many years have you worked full-time (in total)?
please specify [ ] years

5. Please indicate your **age group**
- ○ 18-24
- ○ 25-34
- ○ 35-44
- ○ 45-54
- ○ 55-64
- ○ 65-

6. Your **gender**
○ Female ○ Male

7. How does your office desk typically look like? (Please choose **one** option only)

○ 
Neat office desk

○ 
Messy office desk

○ **Both** examples apply at different times

8. Do you use **physical visual reminders** in your office environment? (e.g. PostIt notes, project documents, other objects)

◯ yes ◯ no

Your email use.

9. How many **years** have you been **using email** regularly?

please specify [ ] years

10. What **email program**(s) are you currently using (most often)? (Please select **all** that apply)

- ☐ Outlook
- ☐ Eudora
- ☐ Netscape Messenger
- ☐ Web-based email service (e.g UofT web mail, yahoo, hotmail)
- ☐ UNIX-based email program (e.g. pine, elm, mail)
- ☐ other, please specify: [ ]

11. How long have you been using your current email program?

please specify: [ ] years [ ] months

12. If you are using Outlook, which **version** of **Outlook** are you using most often?

- ◯ Outlook XP
- ◯ Outlook 2000
- ◯ Outlook 98 or older
- ◯ Outlook Express (any version)
- ◯ don't know which version

13. What do you use email regularly for? (Please check **all** options that apply)

- ☐ **work-related communication**
- ☐ exchange of **work-related documents** (in attachments)
- ☐ **communication** with **family** and **friends**
- ☐ exchange of files with **family** and **friends** (e.g. digital pictures, music in email attachments)
- ☐ to **receive** information from email **mailing and distribution lists**
- ☐ to **communicate** with **customer support**
- ☐ **other**, please specify: [ ]

14 How do you **most frequently feel** about your ability to handle all incoming email? (Please check **one** that applies)

- ◯ on top of things - I am able to handle all incoming email
- ◯ neutral - I do not have an opinion
- ◯ overloaded - I receive too much email to be able to handle it

Incoming email messages.

15. **How many** email messages do you **typically receive** per **day**? (Please include **both** messages from people and from distribution lists)

- ◯ less than 1 per day
- ◯ 1-5
- ◯ 5-10
- ◯ 10-25
- ◯ 25-50

- ○ 50-100
- ○ more than 100

16. **When** do you most frequently **read email** messages? (Please check **one** answer only)

- ○ **almost all the time** as messages arrive and I am at my **computer**
- ○ **almost all the time** on a **computer or** on a **wireless device** (e.g. Blackberry, PDA, cell phone)
- ○ at **specifically set times** (e.g. every morning, after lunch, at 4pm)
- ○ at **random times** (e.g. when I have a break between other tasks or when I happen to be near a computer)
- ○ **other**, please specify:

17. Do you let incoming email **messages interrupt other tasks** that you are performing?

almost always	sometimes	almost never
○	○	○

18. **How often** do you use **search/find** function to find email messages? (Note: Not all email programs support this feature. Please check **one** answer only)

- ○ I use **search/find several times** in **every** email session
- ○ I use **search/find about once** in **every** email session
- ○ I use **search/find** only very **occasionally**, less than once per email session
- ○ I almost **never** use **search/find** function
- ○ My email program **does not have search/find** function
- ○ **other**, please specify:

19. **How often** do you **sort** email messages in inbox or in other folders? (Note: Not all email programs support this feature. Please check **one** answer only)

- ○ I use **sort several times** in **every** email session
- ○ I use **sort about once** in **every** email session
- ○ I use **sort** only very **occasionally**, less than once per email session
- ○ I almost **never** change the **sort order** of email messages
- ○ My email program **does not support sorting** of email messages
- ○ **other**, please specify:

20. **How often** do you use email **message preview or summary**? (Note: Not all email programs support this feature. Please check **one**

answer only)

- I **always** have the **message preview or summary** turned on
- I **sometimes** turn **preview** or **summary** on
- I **almost never** use **preview**
- My email program **does not have** the **message preview** nor **message summary** function
- **other**, please specify:

21. Do you **open** or **preview each** email **message before deciding** what to do with it? (Please check **one** answer only)

- **always**
- in **most** cases, but **not for** obvious **spam** messages
- usually try to **handle email messages without** first **opening** or **previewing** them
- **other**, please specify:

Handling events and to-do's in email.

Terms used:
Event- any activity scheduled to take place at a fixed time, such as a meeting, lecture, doctor's appointment, dinner date, etc.
To-do- a task that should be completed by a specific deadline, for example, a project task, writing a report, replying to an email.

22. Do you **keep** information about **events** and **to-do's together** or **separately?** (Please check **one** answer only)

- **together**
- **separately**
- it **depends** how I **receive** this information, it **stays** where it was received (e.g. in email)
- **other**, please specify:

23. Do you **transfer** information related to **EVENTS** from email messages to another place? (Please check **one** answer only)

- **almost always**
- **sometimes**
- **almost never**, I **keep** my **events** in **email** (events that came through email)
- **other**, please specify:

24. If you keep **EVENTS** in email: (Please check **one** answer only)

- ○ Do you **keep events** in **inbox** only?
- ○ Do you **keep events** together in **one folder** (**not** in **inbox**)?
- ○ Do you **keep events** in **several different folders** depending on their **date & time**?
- ○ Do you **keep events** in **several different folders** depending on the type of an event (e.g. in project-meetings folder, sports events folder, social events folder)?
- ○ **other**, please specify:

25. Do you **transfer** information related to **TO-DO's** from email messages to another place? (Please check **one** answer only)

- ○ **almost always**
- ○ **sometimes**
- ○ **almost never**, I **keep** my **to-do's** in **email** (to-do's that came through email)
- ○ **other**, please specify:

26. If you keep **TO-DO's** in email: (Please check **one** answer only)

- ○ Do you **keep to-do's** in **inbox** only?
- ○ Do you **keep to-do's** in together in **one folder** (**not** in **inbox**)?
- ○ Do you **keep to-do's** in **several different folders** depending on their **deadline (due date)**?
- ○ Do you **keep to-do's** in **several different folders** depending on the type of task to-do (e.g. in project-based folders)?
- ○ **other**, please specify:

27. If you keep **events or to-do's** in email, what **reminds** you about these tasks: (Please check **one** answer only)

- ○ I **use messages** as **reminders** - by keeping them **in inbox** (e.g. I keep them visible in inbox, keep them open)
- ○ I **use messages** as **reminders** - by keeping them **in folders** other than inbox (e.g. I keep them visible in inbox, keep them open)
- ○ I **use messages** as **reminders** by setting **automatic reminders on them** (e.g. using features of an email program)

- ○ I **almost never use messages** as reminders
- ○ **other**, please specify:

Email folders and filters.

28. If you use **email folders**, **why** do you usually **move** an email message to a **folder**? (Please check **all** options that apply)

- ☐ just in case, for a potential future **reference** (no-task messages **not** involving events nor to-do's)
- ☐ when message involves an **event** or a **to-do** - **BEFORE** the start-date or deadline
- ☐ when message involves an **event** or a **to-do** - **AFTER** the start-date or deadline to keep them for a future reference
- ☐ I **never file** email messages, they **stay in the inbox** folder and when deleted, they move to trash folder
- ☐ other, please specify:

29 If you use email folders, do you ever **file email** messages **before** you have **dealt** with them? (Please check **one** answer only)

○ always ○ sometimes ○ never

30. If you use email **folders**, **how** do you **file** email **messages** to them?

all	some	none	
○	○	○	manually
○	○	○	automatically - using email filters (rules)

Outgoing email messages.

31. How many email messages do you typically **send** per day?

- ○ less than 1 per day
- ○ 1-5
- ○ 5-10
- ○ 10-20
- ○ 20-40
- ○ more than 40

32. Do you email yourself **reminders** about events or to-do's?(Please check **one** answer only)

- ○ almost **never**
- ○ **sometimes**
- ○ yes, **regularly**
- ○ **other**, please specify:

33. Do you have any other additional comments? If so, please enter them in the space below:

Submit Form Clear Form

Thank you!

F.3 Web Survey—Results

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		1	4.2	4.2	4.2
	01_5	1	4.2	4.2	8.3
	05_10	8	33.3	33.3	41.7
	10_25	7	29.2	29.2	70.8
	25_50	5	20.8	20.8	91.7
	z100_	2	8.3	8.3	100.0
	Total	24	100.0	100.0	

Table F.1: Number of email messages received per day.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		1	4.2	4.2	4.2
	1_5	10	41.7	41.7	45.8
	10_20	7	29.2	29.2	75.0
	20_40	1	4.2	4.2	79.2
	5_10	5	20.8	20.8	100.0
	Total	24	100.0	100.0	

Table F.2: Number of email messages send per day.

	N	Minimum	Maximum	Mean		Std.
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic
mailyrs	23	3	20	7.35	.721	3.459
Valid N (listwise)	23					

Table F.3: Email experience in years.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	low	11	45.8	45.8	45.8
	high	13	54.2	54.2	100.0
	Total	24	100.0	100.0	

Table F.4: Email experience - grouped into two levels by median (low-high).

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	F	9	37.5	37.5	37.5
	M	15	62.5	62.5	100.0
	Total	24	100.0	100.0	

Table F.5: Gender.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	neat	7	29.2	30.4	30.4
	both	11	45.8	47.8	78.3
	messy	5	20.8	21.7	100.0
	Total	23	95.8	100.0	
Missing	System	1	4.2		
Total		24	100.0		

Table F.6: State of the study participant's office desks.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	ONTOP	15	62.5	65.2	65.2
	NEUTRAL	6	25.0	26.1	91.3
	OVERLOADED	2	8.3	8.7	100.0
	Total	23	95.8	100.0	
Missing	System	1	4.2		
Total		24	100.0		

Table F.7: Frequency of different feelings about email.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	SPECTIME	3	12.5	13.0	13.0
	RANDTIME	12	50.0	52.2	65.2
	ALLTHETIME	8	33.3	34.8	100.0
	Total	23	95.8	100.0	
Missing	System	1	4.2		
Total		24	100.0		

Table F.8: Frequency of reading email at specific times, random times and all the time.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	PROGR_NOSUPPORT	2	8.3	8.7	8.7
	NEVER	10	41.7	43.5	52.2
	OCCASIONALLY	10	41.7	43.5	95.7
	ONCE_SESSION	1	4.2	4.3	100.0
	Total	23	95.8	100.0	
Missing	System	1	4.2		
Total		24	100.0		

Table F.9: Frequency of searching in email.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	NEVER	5	20.8	21.7	21.7
	OCCASIONALLY	11	45.8	47.8	69.6
	ONCE_SESSION	4	16.7	17.4	87.0
	SEVERAL_SESSION	3	12.5	13.0	100.0
	Total	23	95.8	100.0	
Missing	System	1	4.2		
Total		24	100.0		

Table F.10: Frequency of sorting email inbox.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	PROGR_NOSUPPORT	8	33.3	34.8	34.8
	NEVER	7	29.2	30.4	65.2
	SOMETIMES	3	12.5	13.0	78.3
	ALWAYS	5	20.8	21.7	100.0
	Total	23	95.8	100.0	
Missing	System	1	4.2		
Total		24	100.0		

Table F.11: Frequency of using message preview in email.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		1	4.2	4.2	4.2
	ALWAYS	2	8.3	8.3	12.5
	NEVER	12	50.0	50.0	62.5
	SOMETIMES	9	37.5	37.5	100.0
	Total	24	100.0	100.0	

Table F.12: Frequency of transferring event information from email to other places.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		1	4.2	4.2	4.2
	DESKTOP	1	4.2	4.2	8.3
	INBOX	12	50.0	50.0	58.3
	NO	4	16.7	16.7	75.0
	ONE_FOLDER	2	8.3	8.3	83.3
	SEVERAL_ FOLDERS_TYPE	4	16.7	16.7	100.0
	Total	24	100.0	100.0	

Table F.13: Frequency of keeping event information in email.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		2	8.3	8.3	8.3
	ALWAYS	2	8.3	8.3	16.7
	NEVER	9	37.5	37.5	54.2
	SOMETIMES	11	45.8	45.8	100.0
	Total	24	100.0	100.0	

Table F.14: Frequency of transferring to-do's from email to other places.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		1	4.2	4.2	4.2
	INBOX	11	45.8	45.8	50.0
	NO	6	25.0	25.0	75.0
	SEVERAL_ FOLDERS_DATE	2	8.3	8.3	83.3
	SEVERAL_ FOLDERS_TYPE	4	16.7	16.7	100.0
	Total	24	100.0	100.0	

Table F.15: Frequency of keeping to-do's in email.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		1	4.2	4.2	4.2
	AUTOREMINDERS	3	12.5	12.5	16.7
	MSGS_DESKTOP	1	4.2	4.2	20.8
	MSGS_IN_FOLDERS	2	8.3	8.3	29.2
	MSGS_IN_INBOX	9	37.5	37.5	66.7
	NEVER_MSGS	4	16.7	16.7	83.3
	NO	4	16.7	16.7	100.0
	Total	24	100.0	100.0	

Table F.16: Frequency of using messages as reminders.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		5	20.8	20.8	20.8
	NEVER	9	37.5	37.5	58.3
	SOMETIMES	10	41.7	41.7	100.0
	Total	24	100.0	100.0	

Table F.17: Frequency of filing messages into folders before they are dealt with.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid		1	4.2	4.2	4.2
	NEVER	11	45.8	45.8	50.0
	REGULARLY	1	4.2	4.2	54.2
	SOMETIMES	11	45.8	45.8	100.0
	Total	24	100.0	100.0	

Table F.18: Frequency of re-sending email messages as self-reminders.

F.4 Subjective Questionnaires

In both study sessions, after completing the main task, participants were debriefed and asked to fill out a subjective evaluation (Table F.19) and a subjective comparison questionnaires (Table F.20). Study participants were asked to rate their argreement with the following statements on a 5-point Likert scale: strongly disagree (-2), disagree (-1), neutral (0), agree (1), strongly agree (2).

#	Question	UI-Text	UI-Visual
1	I found the WebTaskMail email program to be easy to use	1.13	1.25
2	The WebTaskMail email program would help me to view events and pending tasks.	1.29	1.21
3	I prefer to use a calendar program (e.g., Outlook calendar) to the WebTaskMail program to view task deadlines	0.04	0.54
4	I prefer to use a calendar program (e.g., Outlook calendar) to the WebTaskMail program to view events	-0.21	0.21
5	I prefer to use a calendar program (e.g., Outlook calendar) to the WebTaskMail program to view tasks with no specific time	0.50	0.08
6	I believe that the WebTaskMail program may reduce workload created by handling pending tasks in email.	1.00	1.25
7	The WebTaskMail program provides a better overview of all pending tasks than the standard tabular view of messages (e.g., Outlook inbox and folders)	0.67	1.21
8	Calendar provides a better overview of all pending tasks than the WebTaskMail program	0.00	0.08
9	I prefer to use the standard tabular view of messages (e.g., Outlook inbox and folders) to the WebTaskMail program to view task deadlines	0.58	0.88
10	I prefer to use the standard tabular view of messages (e.g., Outlook inbox and folders) to the WebTaskMail to view events	0.50	0.46
11	I prefer to use the standard tabular view of messages (e.g., Outlook inbox and folders) to the WebTaskMail program to view tasks with no specific time	0.75	0.42

Table F.19: Subjective UI evaluation questions with participant responses (mean).

#	Question	UI-V vs. T
1	I found the WebTaskMail-Text email program easier to use than WebTaskMail-Visual	0.83
2	The WebTaskMail-Visual email program would help me to view events and to-do-s better than WebTaskMail-Text	1.13
3	I believe that the WebTaskMail-Text program may reduce workload created by handling tasks and events in email more than WebTaskMail-Visual	0.79
4	The WebTaskMail-Visual program provides a better overview of all tasks than the WebTaskMail-Text	0.96
5	I prefer to use the WebTaskMail-Visual to the WebTaskMail-Text program to view to-do-s with due-dates	1.13
6	I prefer to use the WebTaskMail-Text to the WebTaskMail-Visual to view events	0.71
7	WebTaskMail-Visual interface was easier to learn than WebTaskMail-Text interface	0.17
8	My performance using WebTaskMail-Visual was better than using WebTaskMail-Text interface	0.88

Table F.20: Subjective UI comparison with participant responses (mean).

Index

Glossary

C

Closure grouping law

Closure grouping law—One of the four original grouping laws of Gestalt psychology, formulated in 1923 by the German psychologist Max Wertheimer (1880–1943) to explain the organization of parts into wholes by the visual system. According to the law, elements that are perceived to form a closed contour tend to be grouped together, so that the array [][][][] tends to be perceived as four rectangular units rather than eight separate elements (Coleman, 2001).

Cognitive ability

Cognitive ability—An ability to perform any of the functions involved in mental activities involved in acquiring and processing information (Coleman, 2001).

Current awareness

Current awareness—In the context of email handling, awareness of incoming email messages (see also *Prospective awareness*).

E

Episodic memory

Episodic memory—A type of long-term memory for personal experiences and events, such as being stung by a bee many years ago, getting married a few months ago, reading a particular book yesterday, or having an egg for breakfast a few minutes ago. Such knowledge is characteristically stored as information about specific experiences and events occurring at particular times and places, and it affords a sense of personal continuity and familiarity with the past. It accounts for only a small proportion of human memory, most of our memories having no basis in personal experience. The concept was introduced in 1972 by Canadian psychologist Endel Tulving, who distinguished it from semantic memory and from procedural memory (Coleman, 2001).

Effect size

Effect size—Measures of effect size in analysis of variance are measures of the degree of association between and effect (e.g., a main effect, an interaction) and the dependent variable. They can be thought of as the correlation between an effect and the dependent variable. This thesis reports effect sizes by using partial Eta squared (η^2). Eta squared and partial Eta squared are estimates of the degree of association for the sample. Eta squared (η^2) is the proportion of the total variance that is attributed to an effect. It is calculated as the ratio of the effect variance (SSeffect) to the total variance (SStotal), that is η^2 = SSeffect / SStotal. The partial Eta squared is the proportion of the effect + error variance that is attributable to the effect. The formula differs from the Eta squared formula in that the denominator includes the SSeffect plus the SSerror rather than the SStotal, that is, η^2 = SSeffect / (SSeffect + SSerror). Values of effect size are interpreted differently in different disciplines. An example of η^2 interpretation: small effect=0.01; medium effect=0.06; large effect=0.14. This values are based on (McGraw, 2003) and were calculated from Cohen d values recommended by (Cohen, 1988).

F

Field dependence-independence

Field dependence-independence—A cognitive style characterized by the propensity to differentiate perceptual and other experiences from their backgrounds or contexts, a person with a weak propensity of this kind being field dependent and a person with a strong propensity field independent. [...] People who score high on abstract reasoning sub-tests of IQ tests, tend to be more field independent than those who score low on such sub-tests (Coleman, 2001).

Flexibility of closure

Flexibility of closure—The ability to hold a given visual percept or configuration in mind so as to disembed it from other well defined perceptual material (Ekstrom, 1976).

Future messages - see Prospective messages

I

Information type—Archived information

Archived information—Information indirectly relevant to the user's current work. The shelf life of archived information is measured in months or years. It is typically highly structured and rather infrequently accessed (Barreau and Nardi, 1995).

Information type—Ephemeral information

Ephemeral information—Information with a short shelf-life (from minutes – a couple of weeks), rarely created by users, almost never filed, and usually kept visible by users on computer desktops to facilitate visual reminding based on spatial location (Barreau and Nardi, 1995).

Information type—Long-term prospective information

Prospective information—Information that refers to the future - to future events or activities. It has longer shelf-life than *ephemeral information*, typically measured in days to months. This information type additionally differs from *ephemeral* in that it has an explicit temporal structure. It can be created by the user, by the user's co-workers, or by other external entities. Also referred to as *future information*.

Information type—Working information

Working information—Information relevant to the user's current work needs. Tends to be frequently accessed and shared. It is created by the user, or the user's co-workers. Its shelf life can be measured in weeks or months (Barreau and Nardi, 1995).

L

Long-term memory

Long-term memory—A type of memory containing information that is stored for periods ranging from about 30 seconds to many decades, often differentiated into *episodic memory* for events and experiences and *semantic memory* for information about the world (Coleman, 2001).

M

Memory span

Memory span—The ability to recall a number of distinct elements for immediate reproduction (Ekstrom, 1976).

N

Non-parametric statistics

Non-parametric methods were developed to be used in cases when the researcher does not know the parameters of the distribution of the variable of interest in the population (hence the name non-parametric). In more technical terms, non-parametric methods do not rely on the estimation of parameters (such as the mean or the standard deviation) describing the distribution of the variable of interest in the population. Therefore, these methods are also sometimes (and more appropriately) called parameter-free methods or distribution-free methods.

P

Parametric statistics

Parametric statistics are based on two general assumptions about data: 1) data are interval or ratio and 2) are normally distributed. When these assumptions cannot be made *non-parametric* statistics should be used.

Pending tasks

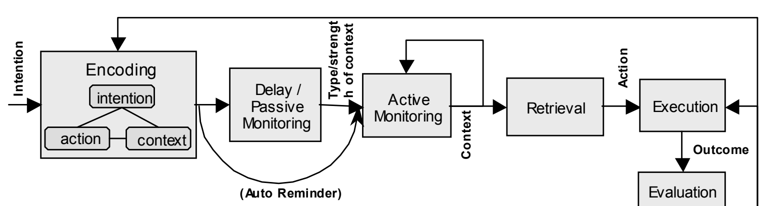
Pending tasks—Activities that are to be performed in the future, such as attending a meeting, visiting a friend, writing a paper, or replying to an email

Prospective awareness

Prospective awareness—Awareness of future tasks and events. The goal of the monitoring processes in *Prospective memory* is to maintain this awareness (Figure 1).

Prospective memory

Prospective memory—Prospective memory is defined either as remembering to do something at a particular moment in the future or as the timely execution of a previously formed intention (Kvavilashvili & Ellis, 1996). Model of prospective memory is shown in Figure 1.



Types of context		
	No cue	External cue
Interruption	Time-based	Event-based
No interruption	---	Activity-based

Figure GL-1. Model of processes involved in prospective memory.

Prospective messages

Prospective messages—Messages that carry *ephemeral*, *working*, and *long-term prospective information*. Prospective messages are related to ***pending tasks***.

R

Retrospective memory

Retrospective memory—Retrospective memory refers to remembering information from the past. It is memory of events, and, in particular, retrospective memory stores personal experiences (also called autobiographical memory).

S

Speed of closure

Speed of closure—The ability to unite an apparently disparate perceptual field into a single concept (Ekstrom, 1976).

T

Task

Task as used in this thesis has two meanings, 1) to refer to tasks embedded in messages (pending tasks); 2) to refer to the tasks users performed in the study (user tasks).

V

Visual memory

Visual memory—The ability to remember the configuration, location, and orientation of figural material (Ekstrom, 1976).

W

Working memory

Working memory—A temporary store for recently activated items of information that are currently occupying consciousness and that can be manipulated and moved in and out of working memory. It consists of a central executive and two buffer stores, called the phonological loop and the visuo-spatial sketchpad (Baddeley, 1986).