

Graphical Browsing of Email Data: A Usability Based Comparative Study

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Abstract: Problem statement: With the rapid growth of the number of email messages and the diverse use of email, people have become overwhelmed by the large volumes of email archives. As a result, email tools that facilitate the browsing of email messages are highly required. This study described an empirical study that aimed to investigate whether the usability of email client can be improved by incorporating graphical visualization techniques to browse email data. **Approach:** Two email visualization approaches, called LinearVis and MatrixVis, were developed for this empirical study which presented email messages based on a dateline together with other email information. The usability of each approach was compared to atypical email tool in terms of locating messages. **Results:** The results demonstrated that LinearVis was the most usable email approach in terms of browsing email messages whereas MatrixVis was found to be the least usable email condition. **Conclusion:** The results showed that usability of email clients can be significantly improved by presenting graphically email messages with only a small volume of hidden email data. Results also indicated that usability of the graphical representations, that hide large volume of email data, can be negatively affected.

Key words: Design, evaluation, interaction, visualization

INTRODUCTION

Email is one of the most widely used applications and Duchenaut and Bellotti called it habitat^[1]. Sometimes, email applications are also used to serve users for task and time management as well as for personal archiving^[2]. Whittaker and Sidner called this as email overload^[3]. The number of email messages and accounts often grows rapidly. For example, it has been estimated that about 31 billion email messages have been sent in 2002^[4]. It has also been shown that the average user gets around 49 email messages a day while high volume users can get more than one hundred^[5]. Email inboxes have become cluttered and difficult to browse as users usually keep their email messages in the inbox for different purposes^[6]. The use of folders and filing has been proposed to organize email messages in the inbox. Becker and Ferreira developed an email tool that automatically classifies email messages using virtual folders^[7]. According to Duchenaut and Bellotti, the use of folders demonstrated problems such as long nesting and lack of use over time^[1]. Yiu et al stated that filing is time consuming and it could be cognitively intensive^[8]. Thus, folders are not always useful especially for high volume email users and some users may also have difficulties generating appropriate folder labels^[9]. Therefore, the

need for more usable email clients that help users to browse email messages efficiently and effectively becomes important.

This study describes an empirical study that was performed to investigate how the various ways of browsing email messages graphically affect the usability of email clients. An experimental email client platform was developed to be used as a basis for this empirical study. The platform provided two types of graphical representation of email messages, both of them present email messages based on a dateline together with other email information. The effectiveness, efficiency and users' satisfaction of the experimental platform were compared to a standard email client (i.e., Outlook Express). This study concludes with the results of this comparative study and some directions of the future research.

Email visualization: Several studies have employed information visualization to represent email messages for different purposes and they can broadly be classified into three categories. These are users' relationship, messages relationship and tasks management. For example, FaMailiar uses visualization techniques to present personal relationships^[10] by allowing users to categorize their contacts into five intimacy categories as well as an automated intimacy weight based on the

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content of the e-mail messages. Messages in faMailiar are presented in calendar-like manner^[10]. Perer, Shneiderman and Oard developed an approach that helps to understand the individuals and communities from the email archive^[11]. Rhythms of relationships were visualized in this project and have shown they could provide context that is necessary for a social scientist^[11]. Perer and Smith developed three email visualizations that capture the hierarchal, temporal and correlation patterns^[12]. One of the goals of these visualization was to improve the understanding of the variation in email users' practice such as the intensity and the duration of relationships with people. Viegas, Golder and Donath developed an email visualization tool called "Themail", which visualized email archives based on the content of email messages, in order to presents relationships between individuals^[13]. It presented a series of keywords in columns arranged along a timeline, where each keyword was shown in a different color. The size of keywords depended on their frequency and distinctiveness. The main goal of these studies was only to show the relationships amongst email users where the usability of email has not been considered.

Message threads, which is the reply relationship for a group of email messages^[14], have been used by many studies to visualizing email messages. Rohall *et al.*^[5,15] developed three visualization techniques and combined them in order to enhance the email inbox. These visualization techniques depend on message threads, time and content of the email messages. In the thread visualization, all the messages that are related by the reply function are shown as connected tree. The relationship between email senders can also be seen in this visualization by displaying the related email messages using different colors. For example, an email message colored purple is from someone outside the recipient's work. Venolia and Neustaedter pointed out that email clients would be more useful if conversation threads were used as the main display for email clients^[16]. They presented a mixed-model visualization that shows the sequence of email messages and reply relationships among the messages of conversation. The users' understanding of message threads was tested and the results showed they were able to understand them. The results of this study showed that users could understand the message threads but the usability of the approach was not considered. Kerr developed a visualization technique called ThreadArcs that shows the reply relationships in messages^[17]. Related messages are connected with arcs and displayed chronologically. It was compared with the existing thread visualizations such as tree diagram and tree

table visualizations and demonstrated to have an advantage over them^[17]. ThreadArcs was used in the reinventing email "Remail" project^[14]. "EzMail" is an email visualization that displayed messages as components of threads in order to provide contextual information^[18]. The thread visualization in this tool was compared with a traditional textual thread and it has been found more usable and preferred^[18]. Perer and Shneiderman stated that threading messages by subject lines and reply relationships does not reflect users behavior^[19]. Therefore, they developed a thread visualization that portrayed users participation in a conversation in addition to the time of sending messages^[19].

Email can be used to perform the management of pending tasks^[20]. Gwizdka focused on how to support this function in email and divided this problem space into two levels (message and inbox)^[20]. Gwizdka developed two email user interface prototypes. The first prototype explored the automatic placement of pending tasks and the second explored the manual arrangement of pending tasks^[20]. Yiu *et al.*^[8] developed an alternative approach of using folders, called TimeStore, to organize email messages in the inbox and to support task management. This approach used the time of receiving the email messages as the determining factor to display email messages. Email messages were organized on X, Y axes where time was presented along the X-axis and the senders on the y-axis. Email messages were displayed as dots and they were interactive (e.g., a user can click on an email message in order to read it). The result showed that the majority of the users thought it was useful^[8]. The task management has been employed in "Remail" project where the received messages can be marked into different categories such as to-do, reminder and appointment^[14]. Some of these marks can be applied automatically where other should be applied manually. Sudarsky and Hjelsvold developed a tool that visualized the email inbox depending on a hierarchal nature of domain names in email addresses such as COM and EDU^[9]. This approach had two hierarchal views. These were a tree generated from the domain names and a temporal view which presented the email messages. In a brief and informal study, significantly improved performance as well as improved overall preferences were demonstrated^[9].

The main goal of most of the previous studies was to visualize email data without fully taking into account whether the usability of email clients was enhanced. Therefore, this study described a comparative usability study aimed to investigate how the various ways of browsing email messages graphically affect the

usability of email clients. This was conducted by comparing the effectiveness, efficiency and users' satisfaction of two experimental email visualizations to a standard email client (i.e., Outlook Express). This study concludes with the results of this evaluation and some directions of the future research.

Experimental platform: LinearVis and MatrixVis:

An experimental email visualization platform was developed using Microsoft Visual Basic 2005 under a Windows XP platform and supported by a database that was designed by Microsoft SQL Server 2005. The platform simulated an email client with a reduced set of functionality but sufficient to serve the empirical study. The platform provided two email visualizations which were called LinearVis and MatrixVis. Both of these approaches presented email messages based on a dateline together with other email information (e.g., senders' email address, time). Table 1 shows the email data that was hidden in both email visualizations in order to reduce the graphical complexity in the email inbox and to avoid the visual overload.

LinearVis: The LinearVis approach presented email messages based on the date and senders' email addresses. Figure 1a shows that the inbox is divided into three parts: dateline, main view and temporal view. The dateline was located at the top part of the inbox which presented all the dates that contained email messages in chronological order where the first date on the far left side was the most recent date that email messages were received and the last date on the far right side was the oldest date. A drop down menu with previous dates (not displayed in the current view) allows the users to view earlier dates. This approach minimized the number of presented dates in order to produce a clear and readable display and to reduce the scrolling operations that would have been required by the users if all dates were presented. The main view presented email messages from the inbox as square boxes which were grouped based on the alphabetically ordered list of email senders on the left side of the inbox. The size of the presented squares decreased according to the number of email messages sent by the email sender (i.e., the larger number of email messages received, the smaller the square).

Table 1: Presented and hidden information in the experimental visualization and the standard email

Conditions	Email data						
	Date	Email address	Subject	Status	Attachment	Priority	Recipients (TO,CC)
Standard email	√	√	√	√	√	√	×
LinearVis	√	√	×	√	×	×	√
MatrixVis	√	×	×	√	×	×	×

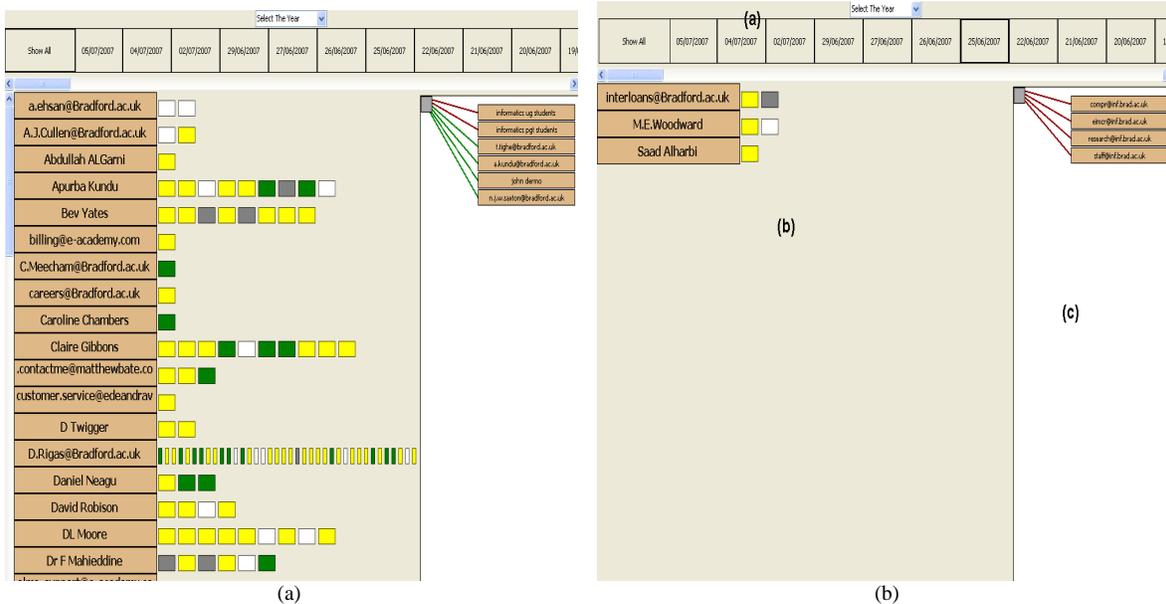


Fig. 1: The inbox of LinearVis with all email messages presented (a) and after selecting a date (b) (A denotes the dateline, B the main view and C the temporal view)

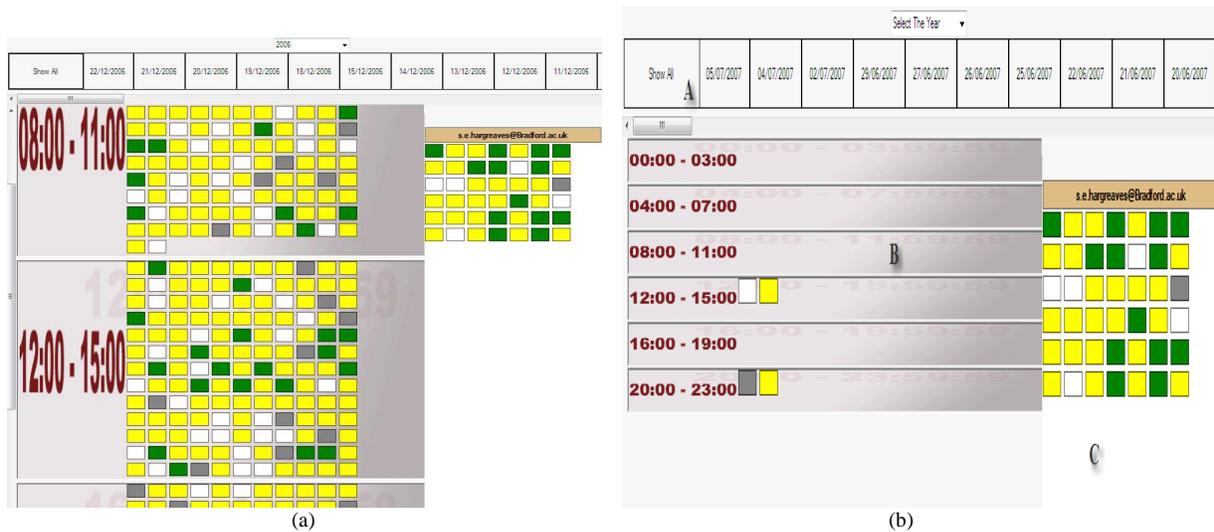


Fig. 2: The inbox of MatrixVis with all email messages presented (a) and after selecting a date (b) (A denotes the dateline, B the main view and C the temporal view)

The filled color of the square communicated to users whether the email message was unread (displayed in yellow), read (displayed in white), replied (displayed in green), or forwarded (displayed in grey). Subject, attachment and priority were hidden in order to reduce the graphical complexity in the main view and to avoid visually overloading the users. This information can be seen by users when the content of the email message is viewed by clicking on the email message in the main view.

The number of displayed messages and addresses in the main view can be reduced by selecting the required date from the dateline (Fig. 1b). The recipients of an email message can be shown in the temporal view by moving the mouse cursor over its icon in the main view. Rather than using the traditional textual way of displaying the recipients (TO, CC) of an email message they are presented using colors. All email addresses connected by green lines are those email messages who have been received as Carbon Copies (CC) and email addresses connected by red lines are those received as normal messages (TO). In order to reduce the amount of presented information on the screen, the email addresses that appear in both TO and CC fields are displayed once and connected by blue lines rather than displaying them twice.

MatrixVis: The MatrixVis approach displayed email messages according to the date and time. Figure 2a shows the way in which the inbox was similarly divided into three main parts: Dateline, main view and temporal view. The dateline section presents the dates using the

same approach as the LinearVis. The main view of the MatrixVis inbox was divided into six timeslots that presented a full day. Each timeslot represented a 4-hour period. Email messages were also presented as square boxes and sorted into timeslots according to the time they were received. In this case, the size of the presented squares was fixed as the size of timeslots could vary according to the number of email messages received within that particular timeslot. Therefore, email messages in each of the timeslots were presented chronologically in rows with up to eleven per row (Fig. 2a). Colors were also used to present the status of the email messages in the same way as in the LinearVis approach.

The size of the timeslots and the number of email messages displayed in the main view can be minimized by selecting a date from the dateline at the top of the inbox (Fig. 2b). The content of email messages and the hidden information (e.g., subject and the recipients (To, CC)) can be seen by clicking on the required email message in the main view. Senders' email addresses were not presented directly in this approach. Therefore, by moving the mouse over an email message, all the email messages sent by the same sender of this message were presented chronologically in the temporal view. The content of email messages presented in the temporal view can be seen by clicking on the required email messages, too.

MATERIALS AND METHODS

Subjects: Thirty users (all were postgraduate computing students) participated in the experiment. All

of them were email users but were not familiar with the experimental visualizations.

Experimental design and tasks: An experiment was designed in order to find out whether the usability of email clients can be improved by visualizing email data. This experiment is a comparative usability evaluation between one of the well-known email clients, outlook express and the proposed experimental graphical email approaches. It was three-conditions, within-subjects design and therefore each subject was asked to perform the experimental tasks in each condition. The email messages were the same under each condition. In order to avoid the learning effect, the order of the conditions was varied between subjects (counter-balanced)^[21]. Table 2 shows the structure of the experiment. Users were required to perform all experimental tasks in a condition and then move to the next one. As shown in Table 2 users were required to fill a satisfaction questionnaire after performing each experimental condition. They were free to use any of the functions that are offered by Outlook Express such as sorting email messages and searching for an email message but they were not able to use these functions in the experimental tool. At the end of the experiment users were also required to choose their most preferred email version. A five minutes demonstration was given for all users prior performing each condition.

Users were required to perform 10 tasks in each experimental condition in each task they had to locate an email message with the provided relevant information such as the date of receiving, the sender's email address and subject. In order to test the control email and the experimental email approaches (i.e., LinearVis, MatrixVis) under various situations, all the data of email messages were taken into account when designing the experimental tasks. In addition, they were designed to be in three complexity levels: easy tasks (3 tasks), medium tasks (4 tasks) and difficult tasks (3 tasks). The location of email messages in the inbox were considered when designing the easy tasks. Therefore, the required email messages in the easy tasks were located at the top of the standard email inbox so users do not need to perform scrolling and searching

operations to find an email message. In order to find out if the hidden email information in both experimental conditions (i.e., LinearVis, MatrixVis) would affect the usability, medium tasks were designed based on increasing the number of required information in email message, especially the hidden ones. For example, in one of the medium tasks users were asked to find an email message by the attachment name with the date. In the difficult tasks, users were mainly asked to find email messages by asking them about the recipients (TO, CC) of the email message beside other information such as the sender's email address.

Hypotheses and measures: The experiment aimed to investigate the effect of the graphical browsing of email messages on the usability of email clients. Therefore, the hypothesis of this experiment was that the LinearVis approach should be more usable than the standard email (i.e., Outlook Express). A similar hypothesis was also formulated for MatrixVis. The usability of a user interface can be measured by taken into account the effectiveness, efficiency and users' satisfaction^[22]. These usability metrics were considered as the dependant variables in this experiment. A detailed analysis based on the tasks complexity levels was also performed on each experimental condition to find out whether the hidden email information in both experimental conditions would affect the usability of email clients.

As the effectiveness of user interfaces can be measured by finding out whether certain tasks can be accomplished successfully^[23], tasks completion rate were considered to measure the effectiveness in this experiment. The efficiency of user interfaces can be measured by finding out the amount of effort required to accomplish certain tasks^[22,23]. Therefore, the efficiency was measured by the time taken by users to perform tasks and the number of actions carried out during the performance of those tasks. For example, one of the actions that can be carried out whilst performing a task in this experiment is clicking on a date in LinearVis or using the search function in the standard email client.

Table 2: Experimental structure and the order in which the conditions were attempted by the users

Users	Order of the presentations of conditions		
	Users' satisfaction	Users' satisfaction	Users' satisfaction
1, 2, 3, 4, 5	Outlook Express	LinearVis	MatrixVis
6, 7, 8, 9, 10	Outlook Express	MatrixVis	LinearVis
11, 12, 13, 14, 15	LinearVis	Outlook Express	MatrixVis
16, 17, 18, 19, 20	LinearVis	MatrixVis	Outlook Express
21, 22, 23, 24, 25	MatrixVis	Outlook Express	LinearVis
26, 27, 28, 29, 30	MatrixVis	LinearVis	Outlook Express

Table 3: Usability metrics and dependant variables

Usability metric	Dependant variables
Effectiveness	Tasks successfully completed
Efficiency	Tasks accomplishment time Number of actions performed to accomplish tasks
Users' satisfaction	Overall users' satisfaction Users' preference

Users' satisfaction is usually measured by knowing the level of users' comfort when using an interface^[23]. Therefore, satisfaction was measured qualitatively by asking users to rate their satisfaction over each email version and asking them about the most preferred email client. Table 3 summarizes the dependant variables used in this experiment.

RESULTS

The performance of each user in each condition was observed and noted in an evaluation form which included the accomplishment time of each task, the number of actions carried out when performing each task and whether each task was successfully completed. The obtained data was analyzed independently according to the usability metrics of efficiency, effectiveness and satisfaction of users. Each graphical email approaches was compared independently to the standard email client.

Effectiveness: In order to find out whether a task was completed successfully, a critical time for task completion was derived. It was computed as follows:

$$CT (T_i) = M (T_i) + 30s$$

- CT = The critical time
- T = An experimental task
- i = The experimental task number
- 30s = 30 sec

Users who took longer than this critical time to complete a task, were considered as not to have completed the task. Figure 3 shows the overall percentage of users who successfully completed all tasks and the overall percentage of tasks completed by all users. Also, it shows the percentage of users who successfully completed each tasks in each of the three experimental conditions. The users who completed all tasks using the experimental conditions (i.e., LinearVis and MatrixVis) are higher than the control condition (i.e., standard email client). Chi-square^[24] results showed a significant difference in the number of users who completed all tasks in LinearVis ($X^2 = 15.8$, $df = 1$, $cv = 3.84$, $p < 0.05$) and MatrixVis ($X^2 = 8.14$, $df = 1$, $cv = 3.84$, $p < 0.05$) when independently compared to the results of the standard email client. A detailed investigation showed that although the statistical results

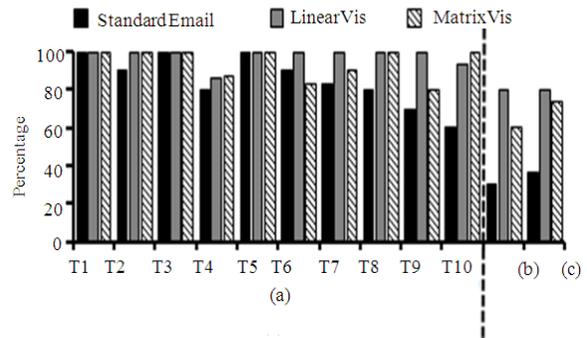


Fig. 3: The percentage of users (a) who successfully completed the ten tasks, (b) all tasks and (c) the tasks completed by all users

suggested that both email visualizations are significantly better than the standard email in terms of number of users who completed all tasks, but 67% of the users who did not complete all tasks in LinearVis because they could not complete Task 4. In this task users were required to find an email message by subject where it is hidden in both experimental conditions. Also, 50% of the users who did not complete all tasks in MatrixVis because they could not complete the same task and the other 50% could not complete the tasks that users wherein required to find email messages by sender's email address where it is hidden in this visualization approach.

The number of tasks completed by all users in the three conditions was also calculated to produce an overall percentage. Figure 3 shows both email visualizations produced higher percentage of tasks completed by all users. Chi-square was also used to test the significance in the number of tasks completed by all users. It showed a significant difference in the number of completed tasks by all users in LinearVis ($X^2 = 5.05$, $df = 1$, $cv = 3.84$, $p < 0.05$) where insignificant difference was shown in MatrixVis ($X^2 = 0.2$, $df = 1$, $cv = 3.84$, $p > 0.05$). Figure 3 shows that the completion rate in both experimental visualizations decreases when the required information of the email messages was hidden. For example, most of the experimental tasks have been successfully completed by all users in LinearVis except Task 4 where the subject of email message was hidden. Also, most of the experimental tasks were successfully completed by all users in MatrixVis except those tasks where users required finding email messages by subject or email address (i.e., Tasks 4, 6 and 7). Therefore, the large scale of hidden information in MatrixVis affected users' performance in terms of number of completed tasks. On the other hand, the percentage of users who completed last three tasks (8-10) using the experimental conditions

(i.e., LinearVis and MatrixVis) was higher than the control condition (Fig. 3). The reason of this increase is that the status of email messages was communicated to users by colors in both visualizations and users did not need to open email messages to find out the recipients (TO,CC) in LinearVis as they were visualized in the temporal view.

Thus, the experimental results showed that presenting email messages graphically such as in the LinearVis could improve the effectiveness of email clients in terms of number of tasks completed successfully and number of users who completed all tasks. Also, the large volume of hidden email data to reduce the graphical complexity in the inbox could negatively affect the effectiveness of email clients.

Efficiency: Figure 4a shows the overall mean time taken by all users to accomplish all tasks in each of the three experimental conditions. The mean time taken by users to complete all tasks in both experimental conditions is lower than the mean time taken in the control condition. Figure 4b shows that the mean number of actions carried out by users in the LinearVis is lower than in the standard email and MatrixVis.

The standard email client required users to take fewer actions than the MatrixVis. The mean time taken to accomplish each task was calculated in order to test the difference among the three conditions. Also, the number of actions carried out by each user in order to perform the tasks in each condition was added together to produce a total number of actions. T-tests^[24] were used to compare each experimental condition independently to the control condition. The results are shown in Table 4. It shows that the results indicated that the time taken to complete experimental tasks was significantly reduced in the LinearVis and not significantly reduced in the MatrixVis. Similarly, the number of actions carried out by users to perform experimental tasks in LinearVis was significantly reduced and significantly increased in the MatrixVis (Table 4). It was also observed that the mean time taken to complete all tasks in the MatrixVis was not reduced more than 9 seconds and the number of actions carried out nearly doubled when compared with the control

condition (the conditions were evaluated with the same users and therefore such a comparison is possible). Therefore, the large-volume of information hiding in MatrixVis is more likely affected users' performance in terms of time and number of actions.

An analysis was performed on each condition independently based on the complexity level of experimental tasks. Figure 5a shows the mean time taken by users to complete each task in all three conditions and Fig. 5b shows the mean number of actions carried out by users to perform each experimental task.

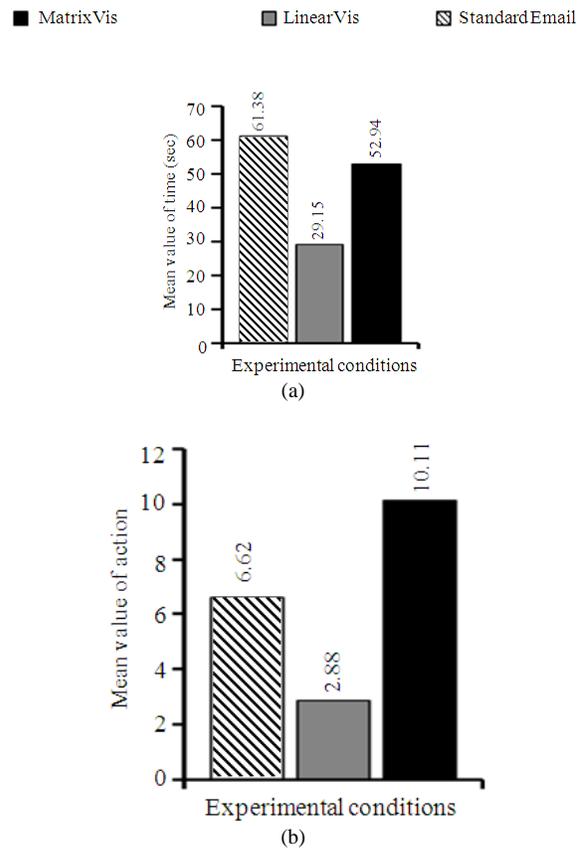


Fig. 4: Overall efficiency results in terms of mean value of tasks accomplishment time (a) and the mean v of actions carried out (b)

Table 4: The results obtained from t-test where it was performed at 0.05 significance level, statistically significant results are displayed in bold

Measure	Time		Number of Actions	
	Standard email Vs LinearVis	Standard email Vs MatrixVis	Standard email Vs LinearVis	Standard email Vs MatrixVis
Easy tasks	$t_4 = 3.30, cv = 2.13$	$t_4 = 3.50, cv = 2.13$	$t_{58} = 0.85, cv = 1.67$	$t_{58} = 0.64, cv = 1.67$
Medium tasks	$t_6 = 0.40, cv = 1.9$	$t_6 = -1.04, cv = 1.9$	$t_{58} = -14.8, cv = 1.67$	$t_{58} = -13.9, cv = 1.67$
Difficult tasks	$t_4 = 2.17, cv = 2.13$	$t_4 = 0.70, cv = 2.13$	$t_{58} = 19.01, cv = 1.67$	$t_{58} = -5.60, cv = 1.67$
Overall	$t_{18} = 1.7, cv = 1.73$	$t_{18} = 0.40, cv = 1.7$	$t_{58} = 11.44, cv = 1.67$	$t_{58} = -9.20, cv = 1.67$

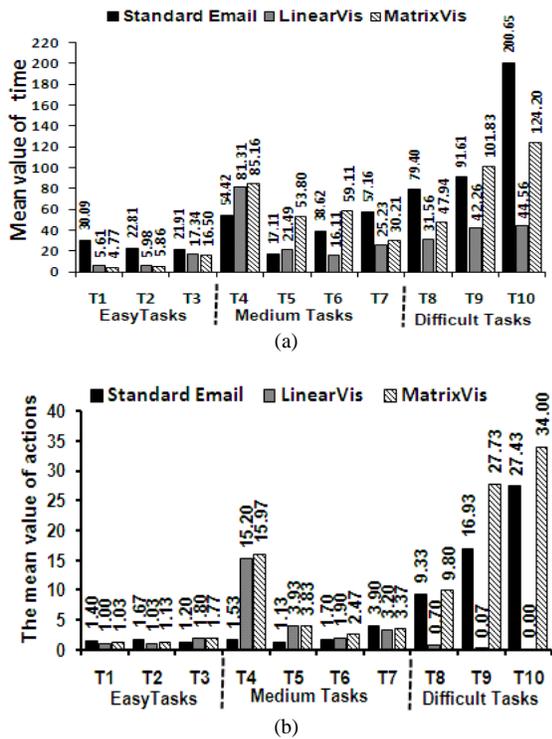


Fig. 5: The detailed efficiency results in terms of the mean time taken (a) and mean number of actions carried out (b) to complete easy, medium and difficult tasks. T1: Location email by date; T2: Locating email by status and date; T3: Locating email by status. Attachment and date; T4: Location email by sender and subject; T5: Location email by sender and priority; T6: Location email by sender, status and attachment; T7: Locating email by date and attachment name; T8: Locating email by sender and CC; T9: Location email by sender, TO and CC; T10: Location email by status, TO and CC

As most of the required email information in the easy tasks are presented directly in the inbox, the mean accomplishment time and the number of actions of these tasks in both experimental conditions is lower than in the control condition (Fig. 5). The number of actions carried out and the accomplishment time of the task 3 have increased because one of the required information (i.e., the attachment) to find the email message was hidden in both experimental conditions. T-test was used to test the difference in the time taken and number of actions carried out to perform easy tasks in each experimental condition independently to the control condition. Table 4 shows that the time taken to complete the easy tasks in both experimental conditions

(i.e., LinearVis and MatrixVis) was significantly reduced when compared to the control condition. Although the mean value of actions carried out to perform easy tasks in both experimental conditions was reduced, the statistical results indicated that this difference was not significant (Table 4). This is because users were required to find email messages by date in this type of tasks and they needed to sort email messages by date in the control condition and to select the required dates from the dateline in both experimental condition as well as they used the experimental conditions for the first time.

Users were required to locate email messages in the medium tasks by subject, priority or attachment. As this type of information was hidden in both experimental conditions, users needed to open the email messages in order to find the required information and complete the task. As a result, the time taken to complete tasks 4 and 5 in the both experimental conditions was higher than in the standard email condition. The number of actions required to be performed by users to complete tasks was similarly higher (Fig. 5b). In addition, as the senders' email addresses were also hidden in the MatrixVis condition, the time taken by users to complete task 6 and the number of actions carried out by users were higher than in the standard email condition (Fig. 5). T-test was also used to test the difference in the time taken and number of actions carried out to accomplish medium tasks in each experimental condition independently to the control condition. Table 4 shows that time taken to perform medium tasks was not significantly reduced in LinearVis and not significantly increased in MatrixVis. Furthermore, the statistical results indicated that the number of actions carried out to perform medium tasks in both experimental conditions was significantly increased (Table 4). Consequently, the hidden email data in both experimental conditions affected users' performance in terms of accomplishment time and number of actions.

Figure 5a shows that the time taken to complete difficult tasks in LinearVis was dramatically reduced. This is because of the recipients (TO, CC) of email messages are presented in the temporal view where they can not be seen in the standard email except if the email message has been opened. Also, most users could complete the difficult tasks in LinearVis without performing any actions (Fig. 5b). Although the time taken by users to complete task 8 and 10 was reduced in MatrixVis condition, time was increased when users performed Task 9 (Fig. 5a). The number of action carried out by users to perform tasks 8, 9 and 10 was dramatically increased, too. This is because of the

senders' email addresses are hidden in this visualization. Table 4 shows a significant reduction in time taken to perform difficult tasks in LinearVis whereas it was not significantly reduced in MatrixVis. The statistical results also indicated that number of action carried out in order to perform difficult tasks in LinearVis was significantly reduced where significantly increased when compared to the control condition. Thus, the detailed investigation and statistical results showed that visualizing email data improved users' performance in terms of accomplishment time and number of actions when performing easy tasks (where most of the required information were visualized) in both experimental conditions and when performing difficult tasks in LinearVis. On the other hand, hiding email data from the view of users in order to reduce the graphical complexity could significantly reduce users' performance in terms of time and number of actions as

shown in the medium tasks of both experimental conditions and the difficult tasks in MatrixVis.

Satisfaction: Users' views were obtained after performing each experimental condition. A questionnaire with 9 statements and 1 to 6 Likert rating scale^[25] was used. Users had to select from 1 to 6 where 1 was indicating a strong disagreement and 6 a strong agreement. For each user, the score of each statement in the questionnaire was added together to produce an overall user's satisfaction score of each condition. The same methodology for scoring Likert scale questionnaires was used by^[25]. Table 5 shows a descriptive analysis of the users' satisfaction data obtained from the satisfaction questionnaires. Figure 6a shows the mean values of users' response of each statement for each of the three conditions.

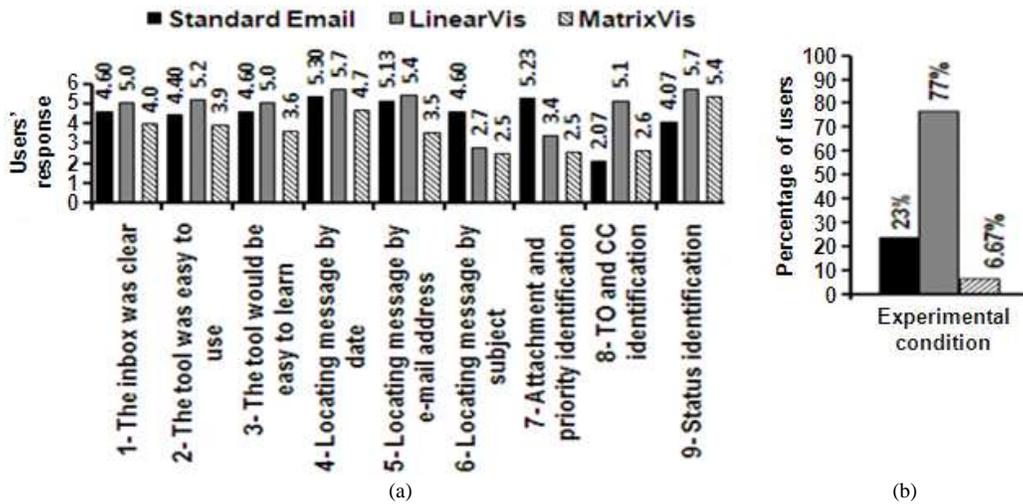


Fig. 6: Satisfaction results: (a): Mean values of users' responses obtained via a questionnaire after each condition which 1 indicates a strong disagreement and 6 a strong agreement; (b): The overall users' preference

Table 5: Descriptive analysis of users' satisfaction

Conditions	Statements in the questionnaire								
	1	2	3	4	5	6	7	8	9
Median									
Control	5.00	4.00	5.00	6.00	5.00	5.00	6.00	2.00	4.00
LinearVis	5.00	5.00	5.50	6.00	6.00	2.00	3.00	5.00	6.00
MatrixVis	4.00	4.00	4.00	5.00	3.50	2.00	2.00	2.50	6.00
Mode									
Control	5.00	4.00	5.00	6.00	6.00	5.00	6.00	1.00	4.00
LinearVis	6.00	6.00	6.00	6.00	6.00	2.00	5.00	6.00	6.00
MatrixVis	4.00	5.00	5.00	6.00	6.00	1.00	2.00	3.00	6.00
Standard deviation									
Control	0.97	0.89	0.93	0.95	1.01	1.28	1.07	1.28	1.44
LinearVis	0.91	0.99	1.24	0.47	1.07	1.72	1.55	0.79	0.45
MatrixVis	1.45	1.65	1.47	1.60	1.85	1.43	1.31	1.30	0.89

Table 6: The frequency and percentages of users who agreed and disagreed in each statement

Statements	Conditions (n = 30)					
	Standard email		LinearVis		MatrixVis	
	Disagreed	Agreed	Disagreed	Agreed	Disagreed	Agreed
Inbox was						
Clear	4 (13.3%)	26 (86.7%)	0 (0%)	30 (100%)	9 (30%)	21 (70%)
Easy to use	2 (6.7%)	28 (93.3%)	3 (10%)	27 (90%)	12 (40%)	18 (60%)
Easy to learn	5 (16.6%)	25 (83.4%)	4 (13.3%)	26 (86.6%)	13 (43.3%)	17 (56.6%)
Locating email by						
Date	1 (3.3%)	29 (96.6%)	0 (0%)	30 (100%)	6 (20%)	24 (80%)
Address	1 (3.3%)	29 (96.6%)	2 (6.6%)	28 (93.3%)	15 (50%)	15 (50%)
Subject	6 (20%)	24 (80%)	20 (66.6%)	10 (33.3%)	21 (70%)	9 (30%)
Identifying e-mail by						
Attachment and priority	3 (10%)	27 (90%)	17 (56.6%)	13 (43.3%)	22 (73.3%)	8 (26.6%)
To and Cc fields	26 (86.6%)	4 (13.3%)	0 (0%)	30 (100%)	25 (83.3%)	5 (16.6%)
Status	10 (33.3%)	20 (66.6%)	0 (0%)	30 (100%)	2 (6.6%)	28 (93.3%)

Table 6 also shows the frequency and the percentage of users who agreed and disagreed on each statement in each condition. Users who selected 1-3 in the scale were considered as users who disagreed with the statements and those who selected 4-6 were considered as users who agreed. They were mainly asked in each questionnaire about the ease of use, ease of learning and the usefulness of each condition. For example, in order to measure the ease of use of each email version, users were required to rate their agreement regarding the clarity of the inbox in each condition and whether the condition was easy to use generally.

The mean values of users' response regarding the ease of use of LinearVis (statements 1 and 2) was higher than the standard email client but it can also be seen that users found that MatrixVis was not easy to use (Fig. 6a). Table 6 also shows that all users found the inbox of LinearVis was clear whereas 4 and 9 users disagreed when asked about the clarity of the inbox of the control condition and MatrixVis respectively. This is because users needed to use the search feature in the control condition whereas email messages are automatically grouped in the inbox of LinearVis based on the senders' email addresses. As email senders are not directly presented in MatrixVis, the percentage of users who did not find it easy to use was the highest amongst all the three experimental conditions (Table 6). Figure 6a shows that mean values of users' responses of statement 3 have also demonstrated that the LinearVis was easier to learn than the standard email client or the MatrixVis. Also, the percentage of users who agreed on that MatrixVis was easy to learn was the lowest amongst the three experimental conditions (Table 6). In fact, the MatrixVis was rated as the most condition difficult to learn. This might be because most of the email data in this condition was hidden especially the sender's email address.

In order to find out the usefulness of the graphical representation of email data and to test whether hiding email information to reduce the graphical complexity in the inbox will affect users' satisfaction, users were asked to rate their agreement regarding the usefulness of locating email messages using different email data. Also, they were asked to rate their agreement regarding the way of presenting some email data in each experimental condition. Figure 6a and Table 6 show that most users found that the dateline in both experimental conditions (i.e., LinearVis, MatrixVis) was useful. In the fifth statement, users were asked to rate their agreement regarding the usefulness of finding email messages using the email address. As it is hidden in MatrixVis, the mean value of users' response was the lowest amongst the three conditions where it was the highest in LinearVis as email senders are visualized in the main view (Fig. 6a). Additionally, 50% percent of the users found that locating email messages using the email address in MatrixVis is not useful (Table 6). Furthermore, subject, attachment and priority of email messages were hidden in both experimental conditions (i.e., LinearVis, MatrixVis). Consequently, the mean value of users' response regarding the usefulness of locating email messages using the subject was dramatically reduced when compared to the control condition (Fig. 6a). Also, Table 6 shows that only 33% percent of the users agreed with the usefulness of locating email messages using the subject in LinearVis and 30% in MatrixVis. In addition, Fig. 6a shows that the mean value of users' response regarding the identification of attachment and priority of email messages in both experimental conditions is lower than the control condition. Also, more than 50% of users disagreed when asked about whether it was easy to identify attachment and priority of email messages in LinearVis and 73% in MatrixVis (Fig. 6a). On the other

hand, users were required to rate their agreement regarding whether it was easy to identify the recipients and the status of email messages in the eighth and ninth statements respectively. Since the recipients of email messages are visualized in the temporal view of LinearVis, the mean value of users' response regarding this statement was the highest amongst the three conditions (Fig. 6a) and all users agreed with the usefulness of visualizing the recipients in LinearVis (Table 6). Moreover, as the status of email messages is communicated to users by colors in both experimental conditions, the mean value of users' response was dramatically increased when compared to the control condition (Fig.6a). All users found that it is useful to present the status of email messages by colors in LinearVis and 93% of them agreed in MatrixVis, too.

T-test was performed on the total number of scores to test the difference in the overall users' satisfaction. The results showed that users were significantly more satisfied with the LinearVis than the standard email client ($t_{29} = 1.77$, $cv = 1.69$, $p < 0.05$) and unsurprisingly with the standard email client than MatrixVis ($t_{29} = -3.39$, $cv = 1.69$, $p < 0.05$). The reason of the control condition being more satisfactory than MatrixVis could be the large scale of information hiding in MatrixVis.

At the end of the experiment users were required to choose the most preferred condition. Figure 6b shows the percentage and number of users who chosen the different conditions. It can be seen that LinearVis was the most preferred condition and the MatrixVis was the least preferred. As the collected data involved counting items that falls into three categories, Chi-Square was used to test the satisfaction data^[24]. It showed significant results in users' preference ($X^2 = 22.4$, $cv = 3.84$, $df = 2$, $p < 0.05$). Thus, the analysis of the obtained data from users' satisfaction questionnaires showed that visualizing email archives can significantly increase users' satisfaction over email clients while hiding email information in order to reduce the graphical complexity can significantly reduce this satisfaction.

DISCUSSION

The analysis of the effectiveness results showed that the graphical presentation of email data in both experimental conditions helped users to complete the experimental tasks. For example, as the status of email message was presented in both experimental conditions (i.e., LinearVis, MatrixVis), most users could complete the tasks wherein the status of email message was required. Displaying the recipients of email messages in

the temporal view of LinearVis helped all users to complete the difficult tasks where not all users could complete them in the control condition. Hiding email data in both experimental conditions affected users' performance in terms of tasks completion. The detailed investigation showed that users who could not complete all tasks in both experimental conditions because they could not complete the tasks that wherein they required to find email messages by hidden information. For example, more than 50% of the users who did not complete all tasks in LinearVis and MatrixVis have not completed the task which they required to locate an email message by subject. The overall effectiveness results indicated that LinearVis was significantly more effective than the standard email and MatrixVis was not significantly improved in terms of effectiveness (Table 7).

The experimental results showed that LinearVis was significantly more efficient than the standard email and MatrixVis was not (Table 7). Although, the graphical presentation of email data improved users' performance in terms of accomplishment time and number of actions carried out in both experimental conditions. The accomplishment time of the difficult tasks was dramatically reduced in both experimental conditions when compared to the control condition because of the presented email data in the temporal view. Also, presenting the recipients (TO, CC) of email messages in LinearVis helped users to perform difficult tasks without carrying out any actions. Although the accomplishment time was reduced when performing difficult tasks in MatrixVis, but hiding the sender's email address led to a significant increase in the number of actions carried out to perform these tasks when compared to the control condition. Users' performance has not only affected by the hidden email data when performing the difficult tasks in MatrixVis, but the statistical results indicated that it has also affected them in both experimental conditions when performing medium tasks. Therefore, hiding email data to reduce the graphical complexity more likely to affect the efficiency of email visualization.

Furthermore, the analysis of the obtained data from users' satisfaction demonstrated that the graphical browsing of email data can improve users' satisfaction over email clients. Most users found the identification of messages status, which is presented by colors in both experimental conditions, was easier than the typical way. They also found that presenting the recipients of email messages in the temporal view of LinearVis more useful than the typical way. On the other hand, the results indicated that the hidden email data has not only affected users' performance in terms

Table 7: A summary of the statistical results (all performed at 0.05 significance level)

Variables						
Conditions	Efficiency		Effectiveness		Satisfaction	
	Completion time	Number of actions	Percentage of users	Percentage of tasks	Overall satisfaction	Overall preference
LinearVis	$t_{18} = 1.7$ $cv = 1.73$	$t_{58} = 11.44$ $cv = 1.67$	$X^2 = 15.8$ $df = 1$ $cv = 3.84$	$X^2 = 5.05$ $df = 1$ $cv = 3.84$	$t_{29} = 1.77$ $cv = 1.69$	$X^2 = 22.4$ $df = 2$ $cv = 5.99$
MatrixVis	$t_{18} = 0.40$ $cv = 1.73$	$t_{58} = -9.20$ $cv = 1.67$	$X^2 = 8.14$ $df = 1$ $cv = 3.84$	$X^2 = 0.2$ $df = 1$ $cv = 3.84$	$t_{29} = -3.39$ $cv = 1.69$	

of effectiveness and efficiency but has also affected them in terms of satisfaction. For example, users found locating email messages using subject in both experimental approaches is more difficult than in the standard email as well as finding email message using a sender's email address in MatrixVis. In overall, the results showed that users were significantly more satisfied with LinearVis than the standard email and with the standard email than MatrixVis (Table 7).

As the results demonstrated, the LinearVis approach significantly improved effectiveness, efficiency and users' satisfaction and the hypothesis that LinearVis should be more usable than the standard email client was confirmed. The similar hypothesis regarding the MatrixVis was rejected because has not significantly improved effectiveness, efficiency and users' satisfaction when compared to the standard email. Table 7 shows a summary of the statistical tests performed in this experiment. The main reason of the MatrixVis being less usable than the standard email client was due to the large volume of hidden email data. LinearVis, on the other hand, had a small amount of email data hidden and it is believed that this contributed to the improved usability.

The dividing of the email inbox into multi coordinated views was found an effective way for organizing the email inbox. The dateline in both experimental conditions (i.e., LinearVis, MatrixVis) helped to group email messages and reduced the time taken by users to locate email messages by date. Also, most users found it easy to use in both email visualizations as shown in the satisfaction results. The temporal view improved the effectiveness and efficiency of both experimental conditions. Furthermore, satisfaction results demonstrated that presenting the recipients of email messages in the temporal view of LinearVis was more useful than the typical way. hence, rather than displaying the recipients on the temporal view only other information can be displayed on it, such as the subject and priority of email

messages. Additionally, using colors was very useful for presenting email data. Therefore, colors can also be used for presenting more email information.

CONCLUSION

This study described an empirical study that was performed to investigate the effect of the graphical representation of email messages on the usability of email clients. Two graphical email visualizations that presented mail messages based on a dateline beside other email information were developed. Various types of email data were hidden in the two email approaches in order to reduce the graphical complexity and to avoid the visual overload. The results demonstrated that a graphical presentation of email data, such as the one in the LinearVis approach, can significantly improve the usability of email clients and large volume of hidden email data, such as the one in the MatrixVis approach, can significantly reduce the usability of email clients.

Many studies have been performed in the last few years to test whether multimodal interaction can enhance the usability of user interfaces. It has been showed that it enhances the usability of interfaces in limited size screens such as PDA devices^[26-28]. Furthermore, previous empirical studies demonstrated that auditory stimuli was successfully applied to communicate data in a variety of interface instances^[29-33]. In some instances, the results of these studies showed that auditory stimuli complemented and aided users to successfully interpret incomplete visual information. Thus, further experiments need to be carried out in order to evaluate the effect of auditory feedback (e.g., speech and non-speech sounds) in the LinearVis approach. In these experiments, some email data will be presented aurally in a multi-modal approach in order to reduce the graphical complexity but also avoid hiding email data from the view of the user.

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