

LinearVis II: Towards More Usable Email Browsing

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Abstract— The results of previous experiments indicated that presenting email data graphically can significantly improve the usability of browsing email messages. However, the results also highlighted some limitations that can negatively affect users' performance. These results were used as a basis to perform a further exploratory study. This paper describes an experimental email tool, called LinearVis II, which was developed to facilitate the browsing of email messages. It was composed of multiple synchronised views that enable users accessing email messages by date, senders and subject at glance from the main view without using typical menus. Attached items can also be accessed from the main view in LinearVis II. In order to investigate the usefulness of browsing email messages in this proposed tool, a comparative usability study was carried out with a typical email client. The obtained data was analysed based on the three well known usability metrics: effectiveness, efficiency and users' satisfaction. The results showed a significant improvement in the usability of browsing email messages in LinearVis II. The results also showed that each component of the proposed tool improved the accessibility of required email messages when compared to typical methods.

Index Terms— Browsing, Effectiveness, Efficiency, email, Graphical, Satisfaction, Usability, Visualisation

I. INTRODUCTION

With the vast growth of the internet and the spread of computer technology, electronic mail (email) has become one of the easiest ways of communication amongst people. It is being used daily in our life and it has been stated that most people check their emails several times a day [1]. Furthermore, Email was called as habitat since most of computer users spend most of their time checking emails [2]. Consequently, the number of messages exchanged by email is rapidly increasing especially that most email users keep their messages for future use.

In general, two types of email systems are being used nowadays: web based email systems such as Yahoo and standalone email clients such as Microsoft outlook. Most of email software in the two types display email messages textually using a chronologically ordered list. Email messages that are not displayed in the focus region of the inbox due to the large amount of archived messages can be found by

sorting messages according to the required properties such as date, sender and subject. For example, email messages must be sorted by date to find an email message sent two months ago and the inbox should be scanned until the required message is found. Furthermore, one of the most frequently used scenarios for finding email messages in most email software is using the conventional search feature where the required information of the message must be entered manually in the search fields. However, this task has become difficult and time consuming especially with the rapid growth of email messages.

Many studies have been carried out (described with more details in Section III) to improve email performance. However, most of these studies focused only in employing new features with email such as task management features as well as developing email tools for specific group of people (e.g. people in work). Nevertheless, the usability of finding email messages in a large email inboxes has not been significantly considered. In an effort to address the usability problems of browsing email messages using the common email data such as date, sender and subject, an experimental email tool was developed which called LinearVis II. This tool is consisted of multiple coordinated views where users can access email messages at a glance from the main view. This tool was developed based on the results of a previous experimental studies [3] [4] [5]. This paper describes the design of the experimental email tool, the empirical study carried out and the obtained results. Finally, it concludes with the finding of this experimental study and highlights the future work.

II. EMAIL PRACTICES

Email is the means of non-face-to-face communication and documents exchange [2]. People who use computer spend most of their time checking emails. the results of the study conducted by [1] showed that users check their email clients continuously (i.e. more than once a day). Whittaker et al stated that email can be the reason of people buying personal computers [6]. Nowadays, Email is being used for diverse of functions which is not designed for [7]. Therefore, they called this phenomenon as email overload. Many studies showed that email has been used for managing tasks, document delivery and archiving messages for future use [7, 8]. For instance, Whittaker et al addressed the possibilities of using email to support the functions of Personal Information Manager (PIM)[9]. As a result of this diversity of use, number of email messages grows rapidly. Venolia et al pointed out that the average email messages exchanged everyday in 2000 were about 9.7 billion email messages. In a later study, it has been estimated that about 31 billion email messages have

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been sent in 2002 [10]. 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 [11].

Users usually leave their email messages in the inbox in order to remind themselves about tasks or actions that should be performed or to be used as a reference for operations have already been performed. In 1996, Whittaker and Sidner conducted a user study that aimed to investigate the practices of email. The results showed that 2482 email messages were left in the email inbox [7]. In a later study, a field study was conducted to investigate how email is used as a work tool [1]. When employees were asked to estimate the number of email messages they send and receive every day, the results showed that 85% of them received 30 messages and 75% sent 10 email messages. Venolia et al also showed that most users leave their email messages in the inbox in order to manage their tasks [8]. Ten years after Whittaker and Sidner study, Fisher et al conducted a study on approximately the same number of users in 1996. The results showed that email inboxes have grown tenfold and most of the email messages were not older than three months [12]. Consequently, email users have become overwhelmed by the amount of email messages in their inboxes. Fisher et al pointed out that as email inboxes are cluttered by large volume of email messages, users usually lose useful information and cannot reply to messages quickly [13]. The results of the study described in [1] showed that as the number of email messages increases the problems and time spent handling email increase. Keyword and full text search can be used to access the stored email messages in the inbox however the overload in the inbox was not resolved and tasks reminder still difficult [9, 13].

Folders can be used to organise email messages and to reduce the amount of presented items in the inbox. Whittaker and Sidner categorise email users in respect of handling email messages into three categories: a) no filers (users who do not use folders); b) filers (users who use folders daily); c) spring cleaner (users who use folder occasionally) [7]. Ten years later, Fisher et al found that this categorisation of email users is still existed [12]. As automatic folder creations and auto classification were shown errors prone [11], users are compelled to create folders manually which is a time consuming task. The limitations of using folders to reduce the inbox overload are well documented in many studies [1, 2, 7, 14]. For example, Whittaker et al described this practice as problematic and stated that it is a cognitively difficult task [9]. Next section shows how information visualisation techniques have been used to improve the efficiency of email clients.

III. EMAIL VISUALISATION

The aims of most studies carried out to improve email clients can be classified into three categories: presenting users' relationship, presenting messages relationships and supporting tasks management. "faMailiar" is One of the email visualisations that have been performed to presents the personal relationships [15]. It enables email users to categorise their contacts into five intimacy categories as well as an automated intimacy weight based on messages data. Messages in "faMailiar" are presented in calendar-like

manner [15]. Perer, Shneiderman and Oard developed a novel approach for understanding the individuals and communities from the email archive [16]. Rhythms of relationships were visualised in the project and have shown they could provide context that is necessary for social scientist [16]. In later work, Perer and Smith developed three email visualisation that capture the hierarchal, temporal and correlation patterns [17]. One goal of these visualisation is 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 visualisation tool called "Themail", which visualised email archives based on the content of email messages, in order to presents relationships between individuals [18]. It presented a series of keywords in columns arranged along a timeline, where each keyword was shown in a different colour. The size of keywords depended on their frequency and distinctiveness. Yu et al developed a visualisation tool called "VisPEAM" which helps users to find their stored email messages through browsing the relationships among email folders and shows the most users who exchange messages in a particular subject [19]. It shows the relationships among folders and users using connected trees that consist of nodes and edges. The main goal of the previous studies was only to show the relationships amongst email users. Although they are efficient in presenting the relationships of users, however cannot be used daily as alternative of the typical email clients such as MS outlook. Such approaches can be useful when they work as add-ons in typical email clients.

Message threads, which is the reply relationship between a group of email messages [20], have been used by many studies for visualising email messages. Rohall et al developed three visualisation techniques and combined them in order to enhance the email inbox [11, 21]. These visualisation techniques depend on message threads, time and content of the email messages respectively. In the thread visualisation 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 visualisation by displaying the related email messages using different colours. For example, an email message coloured purple is from someone outside the recipient's work. One of the limitations of this approach is that email messages are visualised only by date and threads where email messages cannot be classified by email users. For example, users need to classify email messages manually in this approach when looking for email messages sent by a particular person. Venolia and Neustaedter pointed out that email clients would be more useful if conversation threads were used as the main display for email clients [22]. They presented a mixed-model visualisation that shows the sequence of email messages and reply relationships among the messages of conversation. Although users' understanding of message threads was tested and the results showed they were able to understand them, this approach has not been tested and compared against a standard email client. Kerr developed a visualisation technique called "Thread Arcs" that shows the reply relationships between messages [23]. Related messages are connected with arcs and displayed chronologically. It was compared with the existing thread visualisations such as tree diagram and tree table

visualisations and it showed an advantage over them [23]. Thread Arcs was used in the reinventing email “Remail” project [20]. “EzMail” is an email visualisation that displayed messages as components of threads in order to provide contextual information [24]. The thread visualisation in this tool was compared with a traditional textual thread and it has been found more usable and preferred [24]. However, it is similar to typical email clients since folders can be used to store email messages as well as email messages are presented in a similar way of typical email clients. Perer and Shneiderman stated that threading messages by subject lines and reply relationships does not reflect users behaviour [25]. Therefore, they developed a thread visualisation that portrayed users participated in a conversation in addition to the time of sending messages [25]. Inner-Circle is an email tool that organises email conversations (threads) in a people centred way [26]. It is comprised of three interlinked components: people list, conversational view and mailed items. People list contains all email users where those who exchange most email messages over that month. Conversations among group of people can be presented in the conversational view by selecting the required people from the list. Email items that exchanged during the conversation such as attachments and appointments can be presented in the mailed view. Although previous studies showed that threads are efficient feature which should be included in email clients, the date and email users should not be neglected when visualising email archives as users typically use them to locate email messages [27].

Email can be used to perform the management of pending tasks which is the tasks that have to be performed [28]. Gwizdka focused on how to support this function in email and divided this problem space into two levels: message level and inbox level [28]. Therefore, Gwizdka developed two email user interface prototypes one for exploring the automatic placement of pending tasks and the second is for exploring the manual arrangement of pending tasks [28]. Yiu et al developed an alternative approach of using folders, which is called TimeStore, for organising the email messages in the inbox and to support the task management [29]. This approach is using the time of receiving the email messages as the factor for displaying the email messages. Email messages were organised on X, Y axis where time was presented along the X-axis and the senders on y-axis. Email messages were displayed as dots and they were interactive for example, user can click on an email message to read it. This approach has been evaluated to check whether it is useful or not. The result showed that majority of the users thought it is useful [29]. 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 [20]. Some of these marks can be applied automatically where other should be applied manually. Bellotti et al developed email tool called Taskmaster where the main element presented is task rather than the email messages [30]. It is divided into three layers which are: Thrasks, messages view and content. Thrasks, which are threads of tasks, are presented in the top layer of TaskMaster. The email messages that comprised a Thrask can be presented in the middle layer by selecting the thrask from the top layer. The content layer

shows the selected document in the middle layer. As this tool was tested using a filed study, participants reported some technical limitations though it was found powerful tool for tasks management.

Sudarsky and Hjelsvold developed an email tool that visualised the messages based on a hierarchal nature of domain names in e-mail addresses such as COM and EDU [14]. This approach contains two basic views, one of which is a tree generated from the domain names, and the other is a temporal view which presents the email messages. The results of the user study showed a significantly improved performance, as well as improved overall preferences [14]. However, this study was brief and informal. The aim of our experimental programme is nearly similar to this approach but focuses mostly on the usability of browsing email messages. As users usually locate email messages using the common email data such as names, date and subject, the proposed experimental tool exploited this type of information to help users finding email messages easily. The design of LinearVis II is described in more details in the next sections.

IV. EXPERIMENTAL PLATFORM

An email visualisation tool, called LinearVis II, was developed in order to conduct the empirical study. The limitations and drawbacks of the tools used in previous experiments (i.e. LinearVis and MatrixVis) were taken into account when designing this experimental tool. It was developed to facilitate the browsing of email messages using the common email attributes such as senders’ names and date at glance from the inbox. Fig. 1 shows that the inbox of LinearVis II is constructed of the main view, dateline, temporal view, senders’ list and attachment panel. Email messages are presented in the main view of LinearVis II textually in a similar way of most representative email clients. However, it shows email messages that were received in the same month only clustered by days. For example, if email messages were received in only 5 days of a particular month, the main view will presents these messages in five chunks based on the day each message was received on. Messages received on the latest month of the current year will be displayed in the main view when LinearVis II is started. If no message was received on this month, email messages of the previous month will be displayed in the main view and so on. Days chunks are presented chronologically in the main view where the top chunk represents the most recent day and the one located in the bottom is the oldest. Moreover, messages are displayed chronologically in the days chunks and the attributes of messages are presented in the conventional way used in most email clients.

To avoid the repetitive display of the date that messages were received on, it is presented in a gray label at the top of each day chunk. Therefore, the time of receiving messages is only displayed inside the day chunk which clearly shows the chronology of messages. The content of an email message can be shown by selecting it and double click on its subject. Also, the recipients (TO, CC) of an email message can be presented in the temporal view by selecting it from the main view.

Fig. 1 Default view of LinearVis II (A denotes the main view, B the dateline, C the temporal view, D Senders' List, E the attachment panel and F the instant subject search)

Fig. 2 Looking up less active senders

Fig. 3 The main view displaying email messages sent by a sender in a selected month with all attachment displayed in the attachment panel

changed to blue. Also, a bar that shows the sender name will be displayed at the top of the main view. This bar contains a checkbox labelled “Check All “and a button labelled “Deselect”, too. By checking the checkbox in the sender bar the structure of main view will be changed to a list presenting all messages sent by the selected sender in a chronological order (see Fig. 4). Furthermore, un-checking the checkbox will result in removing all the displayed messages except those received on the selected month. The email sender can be deselected by clicking on the button labelled “Deselect” on the sender bar. In this case, all email messages that were received on the last selected month will be displayed in the main view.

Sometimes email users search for files attached with messages rather than searching email messages themselves. For instance, a project member can search for the file contains the project timetable which was sent by the project manager irrespective in which email message was attached to. An attachment panel was developed in LinearVis II in order to facilitate the accessibility of documents and files that were exchanged by email (see Fig. 1). It is directly synchronised with the senders list. Therefore, when a sender is selected all attachments that sent by this sender will be displayed in the attachment panel (see Fig. 3). Fig. 3 shows it is composed of two parts. The first part, which is located in the left side of the panel, shows the applications’ icons that the number of files attached by the selected sender of the same icon’s type. The files’ types were used only for the purpose of the empirical study as more file types can be added to the tool such as image and video files. The second part of the attachment panel shows files’ names and subjects of messages contained the attachments. This list can be filtered to show only one type of files by clicking on the required application’s icon from the left side of the panel (see Fig. 4). Attached files can be accessed by clicking on the required file name from the list. Also, the content of the email message that contains attachment can be accessed by clicking on the subject in the list.

V. EXPERIMENTAL DESIGN AND PROCEDURE

An experiment was designed in order to investigate whether the usability of browsing email messages can be improved. This experiment is a comparative usability evaluation between a representative email client, Microsoft Office Outlook, which was used as control condition and the proposed graphical email approach that was used as the experimental condition (i.e. LinearVis II). The same email inbox that contained 921 real email messages was used in the two conditions. The oldest email message was sent on 06/02/06 where the most recent was sent on 13/10/08. Thirty users were asked to participate in this experiment (see Section VII for more details about users’ profile). As the experiment was designed to be within-subject design, users were required to use both email conditions. Twelve experimental tasks were designed in order to control users’ performance during the experiment and to test the usability of each condition (see Table I). In each task, users were asked to find an email message with the provided relevant information. Most of the practices that could be performed when searching email for

TABLE I EXPERIMENTAL TASKS

Task No	Description
T1	Locating a message by sender name
T2	Locating a message by date
T3	Locating a message by sender and subject
T4	Locating a message by sender and attachment
T5	Locating a message by attachment name
T6	Locating a message by date and subject
T7	Locating a message by sender and date
T8	Locating a message by date and priority
T9	Locating a message by Sender and priority
T10	Locating a message by date and recipients in CC
T11	Locating a message by date and recipients in TO and CC
T12	Locating a message by subject

TABLE II EXPERIMENT FORMAT

Pre-Experiment al Questionnaire	Users	Tasks		Post-Experiment al Questionnaire
		T1- T6	T7 – T12	
	15 Users	Standard Email	LinearVis II	
15 Users	LinearVis II	Standard Email		

messages were taken into account during the design of the tasks. Users were required to find email messages by date beside other email properties such subject and priority of email messages in five experimental tasks. They were also required to find messages by sender email address beside other information such as subject and the existence of attachment in five tasks. One experimental task included the search for an email message by subject only. Furthermore, users were required to find an attached file in one task in order to test the usefulness of the attachment panel which was described earlier. Users were given four training sessions in a typical computer science lab before conducting the experiment. Each session lasted one hour. Moreover, two sessions were allocated for each experimental condition despite most of all users were email users. In these sessions they were trained how to locate and deal with email messages in both experimental conditions. Also, they were asked to perform a training tasks apart of those were performed in the experiment. The experiment was carried out at the same training lab where each user was seated at a computer. In order to avoid users learning from each other, each user was seated where the users sitting beside performing different conditions. In addition, the order of the presentation of experimental conditions was varied between users to avoid the learning affect [31]. Table II shows the format of the experiment. In order to avoid the learning effect, experimental tasks were also rotated on both experimental conditions where each users was required since each task was performed the same number of times in each condition (see Table II). As shown in Table II half of the users started the experiment with carrying out the first six tasks (i.e. T1, T2, T3, T4, T5 and T6) on the control condition and the others started with carrying out the last six tasks (i.e. T7, T8, T9, T10, T11 and T12) on the experimental condition. Users were asked to close

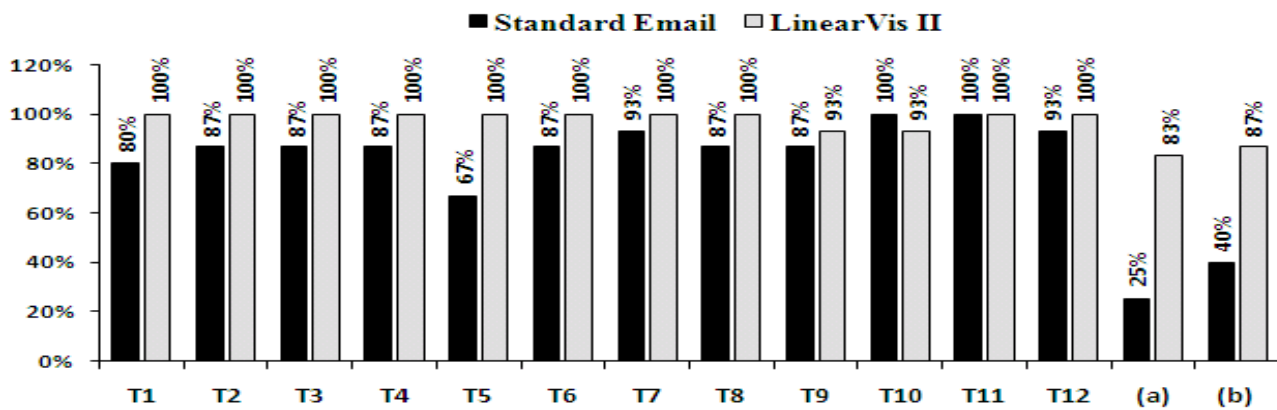


Fig. 5 Users (%) who successfully completed each task, (a) all tasks and (b) the tasks (%) completed by all users

TABLE III USABILITY METRICS AND DEPENDANT VARIABLES

Usability Metrics	Dependant Variables
Effectiveness	1. Tasks completion rate
Efficiency	2. Tasks accomplishment time
	3. Error occurred when performing tasks
	4. Actions performed to complete tasks
Users' Satisfaction	5. Usefulness of email features
	6. Overall users' satisfaction

LinearVis II after performing each experimental tasks to avoid dependency in performing tasks. They were also required to resort email messages by size in the control condition. At the end of the experiment users were required to fill a post-experimental questionnaire to measure their attitude and feeling about each experimental condition.

VI. HYPOTHESES AND VARIABLES

The main hypothesis of this empirical study was that browsing email messages using LinearVis II is more usable than using standard email clients. The usability of software can be measured by taking into account effectiveness, efficiency and users' satisfaction [32] [33] [34]. The dependant variables used in this experiment were classified according to these usability metrics (see Table III). Tasks completion rate was considered to measure the effectiveness of each experimental condition. Moreover, tasks accomplishment time, error occurred whilst performing tasks and actions needed to complete tasks were measured in order to test the efficiency of each experimental condition. Users' satisfaction over each condition was measured qualitatively through a post-experimental questionnaire. Users were required in this questionnaire to rate the usefulness of locating email messages and state the overall level of their satisfaction over each condition. Thus, the main hypothesis was decomposed into more specific hypotheses based on the usability metrics applied in this experiment. These hypotheses are:

- Browsing email messages in LinearVis II should be more effective than using than the standard email in terms of tasks completed successfully.
- Browsing email messages in LinearVis II should be more efficient than using than the standard email in terms of tasks accomplishment time, errors occurred whilst

performing tasks and actions required to complete tasks.

- Browsing email messages in LinearVis II should be more satisfactory than using than the standard email in terms of overall satisfaction score and the usefulness of locating messages features.

VII. SAMPLE

In order to test the experimental hypotheses, thirty users were recruited in this experiment. All of them were undergraduate students doing a bachelor degree in computer science. Moreover, they were all male and aged between 18 and 25 years. Most of them use web-based email system and few of them indicated they use a standalone email client when asked about type of email software they use. Also, most of them stated that they check their email continually (i.e. once the email message arrives) or several times a day when asked about how often they check their emails.

VIII. RESULTS

The performance of each user was video recorded in each experimental condition. Each recording was observed independently in order to measure tasks accomplishment time, errors occurred when performing tasks and actions needed to complete tasks. Furthermore, users' satisfaction data was collected from post-experimental questionnaires. This experimental data was analysed independently according to effectiveness, efficiency and users' satisfaction.

A. Effectiveness

A critical time was derived for each task in order to find out whether it was completed or not. Users who took longer than this critical time to complete a task were considered as not to have completed the task. The percentage of users who completed each experimental task in both experimental conditions was calculated. Fig. 5 shows the percentage of users who completed each tasks successfully in each experimental condition. It also shows that most experimental tasks were completed in LinearVis II with higher percentage of users than the control condition. For instance, senders' list helped all users to complete the first experimental task (T1) where 20% of them have not completed it in the control condition. The observation of users' performance showed that users used senders' list frequently. For example, most users

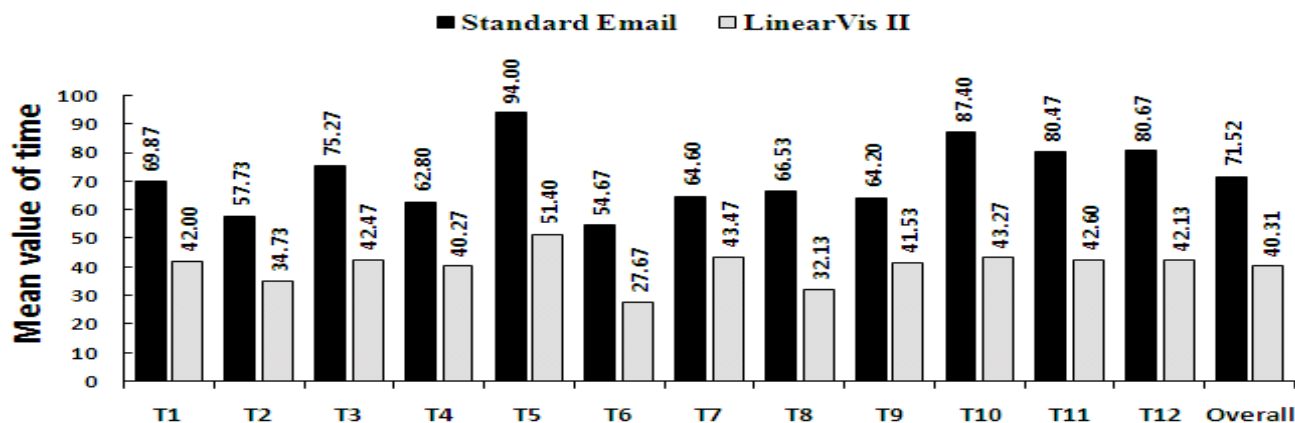


Fig. 6 Mean value of tasks accomplishment time

(93%) completed task 3 in LinearVis II through the senders' list although they could perform the task using the instant subject search feature since they were required to find the email message by sender and subject (see Table I). Furthermore, most experimental tasks that users wherein required to find email messages by date (task2, task6, task8 and task11) were completed by all users in LinearVis II while only one experimental task (task 10) was completed by all users in the standard email. Thus, the dateline in LinearVis II was found more effective in terms of tasks completion for locating messages than using the standard sorting process. Fig. 5 shows a notable difference between the percentages of users who completed task 5 in both conditions. Users needed to open email messages in the control condition in order to find the required attached file therefore only 67% of them have completed the task within the critical time. In contrast, the attachment panel in LinearVis II helped all users to complete the task within the critical time. Fig. 5 shows that the percentage of users who completed the last experimental task (task 12) in the control condition was slightly lower than LinearVis II because both conditions used almost the same approach for finding messages by subject.

The overall percentage of users who completed all experimental tasks in each condition was also calculated. Fig. 5 shows that 60% (9 users) of users have not completed all tasks in the control condition where only 13% (2 users) have not completed all tasks in LinearVis II. Moreover, the overall percentage of tasks completed by all users in each condition was calculated. Fig.5 shows that only 25% (3 tasks) of the experimental tasks were completed successfully by all users in the standard email where 83% (10 tasks) was completed in LinearVis II. Chi-square was performed on the number of users who completed all tasks to test the difference between both conditions. The result showed that tasks completion rate in LinearVis II is significantly higher than the control condition ($\chi^2 = 7.03$, $df = 1$, $cv = 3.84$, $p < 0.05$). Thus, browsing email messages in LinearVis II is more effective than the standard email.

IX. EFFICIENCY

1) Tasks Accomplishment Time

The mean value of time taken to accomplish each task was calculated in both experimental conditions. Fig.6 shows the mean value of time taken to accomplish each task in both experimental conditions and also shows the overall mean value of time taken to complete all tasks. It can be noticed from Fig.6 that all tasks were completed in LinearVis II with reduced time in comparison with the control condition. Senders' list in LinearVis II helped users to complete the tasks in which they were required to find email messages by sender (i.e. task1, task3, task4, task7 and task9) faster than in the control condition. For instance, users took longer time to complete the first experimental task (task 1) in the control condition than LinearVis II although the required sender was not located amongst the most active senders in the list. Moreover, it helped to reduce the time taken to complete the tasks in which users required to find messages by sender alongside attachment or priority (task 4, task 9) although this type of data was presented in a similar way in both conditions. The dateline in LinearVis II has also helped in the reduction of time taken to accomplish experimental tasks. Fig.6 shows that users could complete task 2 (i.e. in this task, users were required to find an email message by a date) using the dateline in LinearVis II faster than using the typical way used in the control condition. Furthermore, the time taken to accomplish task 6 in LinearVis II was reduced when compared to the control condition despite users were required to select the year from the previous years' menu. Fig.6 shows that the time taken to accomplish the tasks in which the recipients of email messages were required (task 10, task 11) was dramatically reduced (i.e. nearly to half) in LinearVis II. This is not only because the dateline has helped users to locate the required date quickly but also the presentation of the recipients in the temporal view. In contrast, users needed to open email messages and check the recipients of each message in order to complete this type of tasks in the control condition. Fig.6 shows that time taken to complete task 5 was also dramatically reduced in LinearVis II when compared to the control condition.

As users were asked in this task to find an attached file by

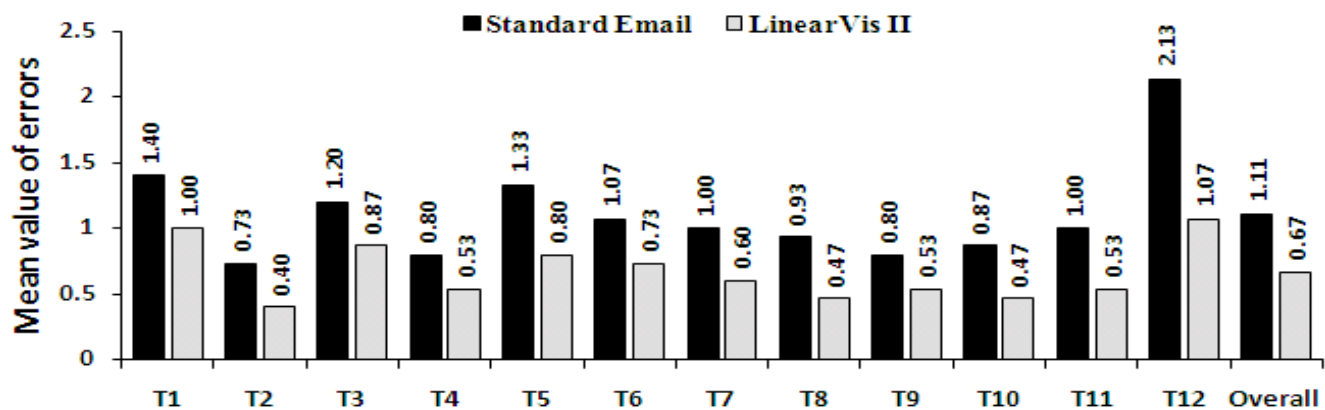


Fig. 7 Mean value of errors occurred whilst performing tasks

sender name, they needed to open most of the messages sent by this sender and contained attachments to check the required file's name in the control condition. In contrast, the coordination between senders' list and the attachment panel in LinearVis II helped users to find the required file rapidly. In the last experimental task (task 12), users were asked to find a message by subject hence they needed to use the menus of the control condition to activate the search window and then type the required subject. On the other hand, users used the instant subject search textbox located in the inbox of LinearVis II to accomplish this task. Thus, time taken to complete this task (task 12) was noticeably reduced in LinearVis II when compared to the control condition.

The overall mean time of accomplishing all experimental tasks was calculated in each condition. Fig.6 shows that mean time taken to accomplish all tasks in LinearVis II was extremely lower than the control condition. T-test was performed on the tasks accomplishment time in order to test the difference between both conditions. The results demonstrated that the time taken to complete experimental tasks in LinearVis II was significantly lower when compared to the control condition ($t_{11} = 13.07$, $cv = 2.2$, $p < 0.01$). Therefore, browsing email messages in LinearVis II is more efficient in terms of tasks accomplishment time than the control condition.

2) Errors Rate

Fig.7 shows the mean value of errors occurred whilst performing each experimental task in the two conditions. It also shows the overall mean value of errors in each experimental condition. It can be clearly seen that users made less errors when carrying out most of the experimental tasks in LinearVis II. The observation of users' performance showed that one of the frequent errors that were observed when performing the experimental tasks in the control condition is miss-noticing the required email messages due to the excessive use of sorting. For example, most users did not notice the required sender name (i.e. "mohammed Al-ashikh") when performing the first experimental tasks after sorting messages according to senders and were imposed to use the menus to activate the search window and hence descended in errors. Deviation from the right path of carrying out tasks was also frequently observed in the control condition for example sorting messages by date when the

sender is required, or using the menus for finding a message by date. However, many types of errors were observed when performing the experimental tasks in LinearVis II. For instance, the most frequent error that was observed during performing the experimental tasks in which users required to use the senders' list (task 1, task 3, task 4, task 7 and task 9) is forgetting to click on the sender's name to display messages belong to this sender after typing it in the search field. Also, typing the sender's name in the textbox dedicated for subject search and vice versa. Though, senders' list helped users to perform tasks with reduced error rate when compared to the control condition (see Fig.7). Furthermore, forgetting to select the year from previous years' menu in LinearVis II is one of the common errors noticed when carrying out experimental tasks in which users required to find messages sent in a previous year. In task 6, most of the users who carried out errors clicked on the button labelled "May" in the dateline without selecting "2007" from the menu. Nevertheless, Fig.7 shows that the dateline helped in the reduction of the error rate in LinearVis II when compared to the control condition (task 2, task 6, task 8, task 10 and task 11). The attachment panel in LinearVis II helped users to accomplish task 5 with a reduced error rate than the control condition (see Fig.7). However, the observation of users' performance showed that most of them had difficulties recalling the attachment panel. For example, the most frequent error occurred whilst performing this task is that users displayed all messages of the selected sender in the main view then remembered to use the attachment panel. This is because of users' unfamiliarity with this new approach of presenting attachments. Thus, this type of errors is more likely will be avoided when the familiarity of users increased. Fig.7 shows that users carried out fewer errors when performing tasks 10 and 11 in LinearVis II when compared to the control condition. This is because of the recipients of messages are displayed in the temporal view of LinearVis II while messages needed to be opened in the control condition to find out the required recipients and therefore more errors were occurred. The mean value of errors was increased when performing the last experimental tasks in both conditions due to the spelling mistakes when typing the required subject (see Fig.7). Additionally, one of the most frequent errors occurred by users whilst carrying out this task in the control condition is misplacing the search command. However, the instant subject search feature in LinearVis II helped users avoiding this

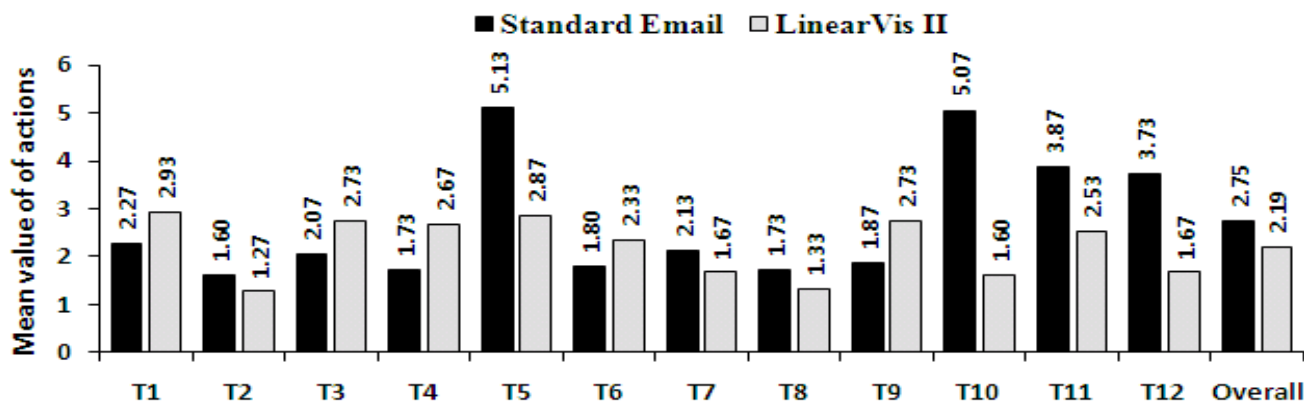


Fig. 8 Mean value of actions carried out to accomplish tasks

type of errors and therefore the mean value of errors was reduced (see Fig.7).

The frequency and percentages of users who completed each experimental task without carrying out any errors in each condition was calculated. The result demonstrated that the number of users completed most experimental tasks without any error in LinearVis II is higher than the control condition. It also shows that the number of users who performed the last six experimental tasks in LinearVis II was increased when compared to the number of users who performed the first six tasks in the control condition despite of considering the errors of the last experimental task that were not caused by the system (i.e. spelling mistakes). Consequently, errors occurred in LinearVis II most likely caused by users' unfamiliarity with the system and hence can be avoided over time. Paired t-test was performed on the number of errors occurred whilst performing experimental tasks in order to test the difference between experimental conditions. The results showed a significant reduction in the number of errors occurred in ($t_{18} = 3.41$, $cv = 1.7$, $p < 0.01$) LinearVis II when compared to the standard email. Thus, browsing email messages in LinearVis II is more efficient in terms of error rate than the standard email.

3) Number of Actions Carried out

Fig.8 shows the overall mean value of number of actions carried out to perform all experimental tasks in both experimental conditions. It also shows the mean value of actions carried out to accomplish each experimental task in both conditions. The overall mean value of actions carried out to perform experimental tasks in LinearVis II was slightly lower than the control condition (see Fig.8). Paired t-test was applied on the number of actions carried out in order to test whether this difference is significant. The results indicated that number of carried out to accomplish tasks in LinearVis II was not significantly reduced when compared to the control condition ($t_{11} = 1.33$, $cv = 1.7$, $p > 0.05$). Fig.8 shows that most experimental tasks were completed in LinearVis II with reduced number of actions except the tasks in which senders' names were required (task 1, task 3, task 4 and task 9). In task 1, users were required to find an email message sent by a non-active email sender therefore, the increase in number of actions were expected as they needed to type the required sender's name, select it and display all messages respectively.

Although they were required to find email messages by the most active senders, which were located amongst the top 10 senders at the senders' list, in the rest of this type of tasks but the mean value of actions carried out was nearly the same when compared to the first experimental task (see Fig.8). The reason behind this increase is that unfamiliarity of users with the names and addresses in the experimental inbox entailed them to find active senders' in the same way of non-active ones. The mean value of number of actions carried out to perform task 7 in LinearVis II was lower than the control condition although users were required to find the email message by a sender's name (see Fig.8). This is because they were required to use the dateline as the date was required and the required sender was the most active (i.e. the first sender in the list) sender, too.

Fig.8 shows that the dateline in LinearVis II helped users to accomplish tasks 2, 8, 10 and 11 with reduced number of actions when compared to the control condition. Observation of users' performance showed that some users sorted messages several times by date in the control condition in order to find the required email message. On the other hand, only one action (i.e. month selection) was required to find an email message sent in the current year and the maximum number of actions required to find a message sent in a previous year is two (i.e. year and month selection). Fig.8 shows that task 6 was performed in LinearVis II with a slight increased number of actions when compared to the control condition though the date was required in this task. Only five users completed this task in LinearVis II with number of actions higher than expected (i.e. two actions). This is because of the frequent error occurred whilst performing this tasks, which is forgetting to select the previous years, has affected users' performance in terms of number of actions. Fig.8 shows that the attachment panel in LinearVis II has also helped users performing task 5 in LinearVis II with a considerable reduced number of actions (i.e. nearly 50%) when compared to the control condition in spite of the occurrence of the un-required actions due to recall errors (see previous section). Furthermore, the presentation of the recipients in the temporal view of LinearVis II helped users to accomplish tasks 10 and 11 with a lower number of actions than the control conditions where they needed to open email messages to find the required one (see Fig.8). Number of actions carried out to perform the last experimental task in the control condition was considerably higher than the

experimental condition (i.e. LinearVis II). This is because the search feature in the control condition was located amongst the menus where it was located in the main view of the experimental condition. Additionally, instant search feature was implemented in the experimental condition where it was not used in the control condition.

Since the results showed that the unfamiliarity of users with the names and addresses in the experimental inbox has affected their performance in terms of number of actions when carrying out the tasks that used senders' details in LinearVis II, paired t-test was performed on the number of actions carried out excluding this type of tasks (i.e. task 1, task 3, task 4, task 7 and task 9) although some of them produced less actions in LinearVis II such as task 7. The aim of this test is only to investigate the difference between LinearVis II and the control condition in locating email messages by date, subject and attached files. The results indicated that number of actions carried out to perform the tasks in which senders were not required (7 tasks) to find email messages LinearVis II is significantly lower than the control conditions ($t_6 = 2.56$, $cv = 1.94$, $p < 0.05$). Thus, browsing email messages by date, subject and attached files in LinearVis II is more efficient in terms of number of actions than the control condition. Furthermore, number of actions required to find email messages in LinearVis II is more likely will be reduced when users' email data is used in the experiment or users get more familiar with the experimental email data.

B. Users' Satisfaction

Each user was asked to fill a post-experimental questionnaire at the end of the experiment in order to obtain their views and opinions regarding the experimental conditions. It was 1 to 5 Likert rating scale with 10 statements. It consisted of three sections; the first one contained four statements regarding the layout of the experimental conditions and the ease of use. Users were required to rate their level of agreement with each statement in each experimental conditions using the scale where 1 indicated a strong disagreement and 5 a strong agreement. The second section contained five statements regarding the usefulness of finding email messages in each experimental condition. Similarly, users were asked to rate the level of difficulty of searching features in each statement using the scale where 1 indicated very difficult and 5 indicated very easy. The last section of this questionnaire included one statement about the overall users' satisfaction over each experimental condition. The same scale was used in this section to rate the overall level of satisfaction where 1 was indicating very frustrated and 5 very satisfied. The obtained data was analysed in two independent ways. First, the score of each statement in the questionnaire was added together to produce an overall satisfaction score for each user. The mean value of satisfaction score in the control condition was 26.93 where it was 42.47 in the experimental condition (i.e. LinearVis II). Paired t-test was used to test whether this difference is significant. The results indicated that LinearVis II was significantly more satisfactory than the control condition ($t_{29} = 16.41$, $cv = 1.61$, $p < 0.01$). Each statement in the questionnaire was analysed independently in the second way. Fig.9 shows the median

TABLE IV STATISTICAL RESULTS OF WILCOXON TEST

Question No	Results
Q1	Z=3.17, cv=165, p<0.05
Q2	Z=4.11, cv=165, p<0.05
Q3	Z=4.10, cv=165, p<0.05
Q4	Z=4.52, cv=165, p<0.05
Q5	Z=4.32, cv=165, p<0.05
Q6	Z=4.63, cv=165, p<0.05
Q7	Z=4.21, cv=165, p<0.05
Q8	Z=4.96, cv=165, p<0.05
Q9	Z=3.76, cv=165, p<0.05
Q10	Z=3.83, cv=165, p<0.05

value of users' response regarding each statement in the two experimental conditions. Also, Fig.10 shows the frequency of users who were satisfactory and dissatisfactory with each statement in the two experimental conditions. Although the control condition is one of the widely used email clients, the median value of users' response regarding the organisation of the inbox, ease of use and ease of learning was lower when compared to LinearVis II (see Fig.9). Fig.10 shows that the number of users who agreed with statement regarding the layout and the ease of use (i.e. the first section in the questionnaire) of LinearVis II is notably are higher than the control condition. Also, it shows that the number of users who disagreed with the same statements is considerably higher in the control condition than LinearVis II. For instance, only two users disagreed when they were asked about the clarity of the LinearVis II inbox (i.e. question 1) and the ease of learning (question 2) where 6, 16 users respectively disagreed when asked about the same questions regarding the control condition.

Wilcoxon Signed Ranks test was performed on the satisfaction scores of each statement in order to test the difference between both experimental conditions. The results are shown in Table IV. This test was used because of the obtained data is not normally distributed and considered as nominal data [35]. The results indicated that LinearVis II is significantly more satisfactory in terms of the clarity of inbox, ease of use and ease of learning (Q1, Q2, Q3 and Q4) when compared to the control condition (see Table IV).

Fig.9 shows that the median value of finding email messages by sender (i.e. question 5) in LinearVis II is higher than the control condition. Also, twenty four users (80%) who rated that locating email messages by sender in LinearVis II is easy while none of them found it easy in the control condition (see Fig.10). Conversely, 40% of the users rated that finding messages by sender in the control condition is a difficult task while 6% only found it difficult in the experimental condition. The results of Wilcoxon Signed test demonstrated that finding email messages by the senders' list in LinearVis II is significantly more satisfactory than the traditional way used in representative email clients (see Table IV). In question 6, users were asked to rate the level of difficulty of finding email messages by date. Fig.9 shows that the median value of users' response in LinearVis II is higher than the control condition. The number of users (86%) who found this task easy in LinearVis II is also remarkably higher than those who found it

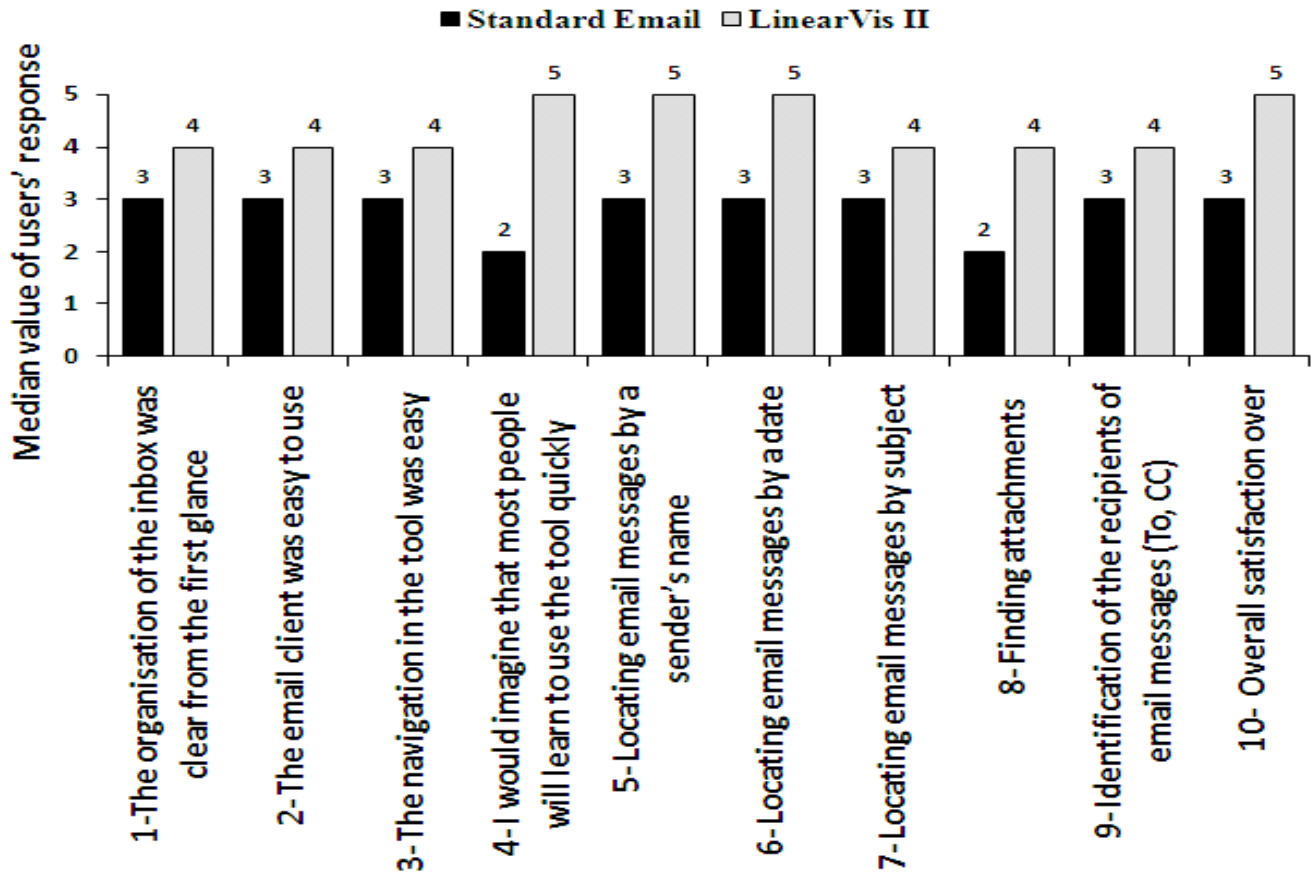


Fig. 9 Median value of users' response

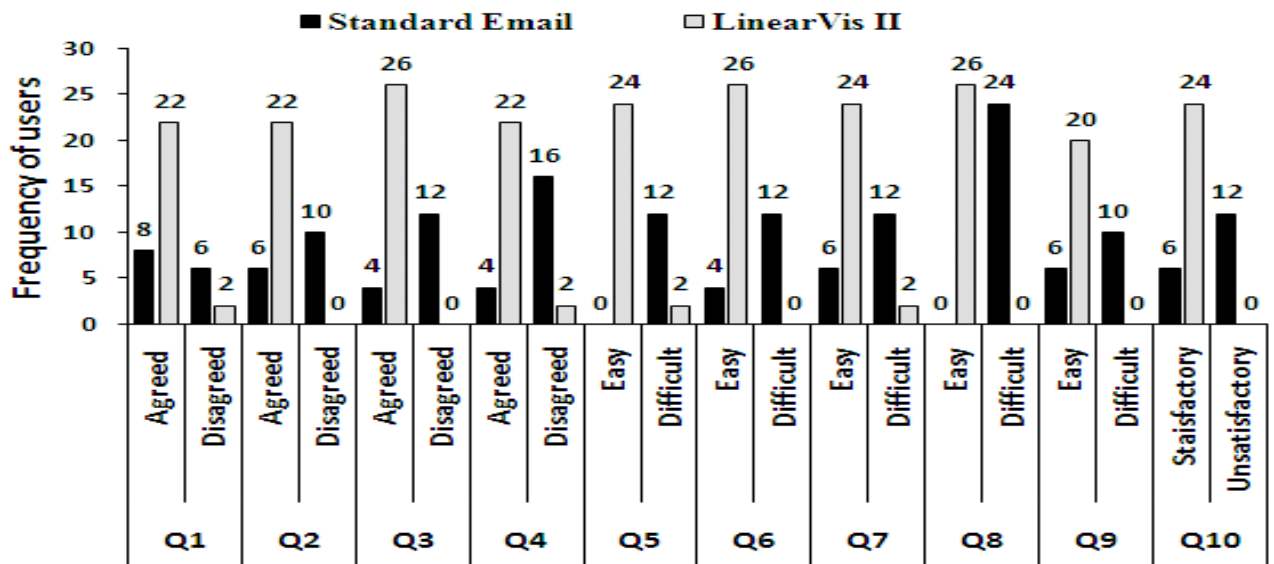


Fig. 10 Frequency of users who are satisfactory and dissatisfactory with the questionnaire statements

easy in the control condition (13%) (see Fig.10). Moreover, none of the users found that locating email messages by date is difficult in LinearVis II while nearly half of them found it difficult in the control condition. Statistical results showed that locating email messages using the dateline is significantly easier than the traditional way used in the control condition (see Table IV). Although both experimental conditions used a similar way of locating email messages by subject, the median value of users' response for LinearVis II is slightly higher than the control condition. This is because the search textbox was located in the main view and it used the instant search feature (see Section 4). Moreover, the number of users who found the instant subject search in LinearVis II (80%) is considerably higher than the control condition (20%). On the other hand, nearly half of the users (40%) found locating messages by subject in the control condition is a difficult task while only two users found it difficult in LinearVis II (see Fig.10). Statistical results indicated that locating email messages by subject in LinearVis II is significantly more satisfactory when compared to the control condition (see Table IV). Fig.9 shows that the median value of users' response regarding finding attachments in LinearVis II is considerably higher than the standard way. Also, Fig.10 shows that most users (86%) found this task is easy and none of them found it difficult. In contrast, none of the users found that locating attachments in the control condition is an easy task and most of them (80%) found it difficult. The results of Wilcoxon Signed test indicated that the attachment panel used in LinearVis II was significantly easier than the traditional way of finding attachments. The majority of users found that presenting the recipients of email messages in the temporal view of LinearVis II is also easier than the control condition (see Fig.9 and Fig.10). Statistical results showed that the identification of recipients in LinearVis II is significantly easier than the control condition.

Finally, users were asked in the last question about their overall satisfaction over each experimental condition. Fig.9 showed that the median value of users' response regarding the experimental condition is higher than the control one. Fig.10 shows that the majority of users were satisfied with LinearVis II and none of them found it unsatisfactory tool. Conversely, 40% of the users were not satisfied with the control condition and six users only were satisfied. Statistical results demonstrated that LinearVis II is significantly more satisfactory than the control condition. As shown above, the results of the overall analysis showed that LinearVis II is significantly better than the control condition in terms of satisfaction scores and the statistical results of each statement in the questionnaire showed a significant advantage of LinearVis II over the control condition. Hence, browsing email data in LinearVis II is more satisfactory than the standard email.

X. DISCUSSION

The experimental results showed that the multiple coordinated views in LinearVis II improved the usability of browsing email messages using the common email properties such as date, senders' details and subject. Statistical results showed that LinearVis II has significantly increased tasks

TABLE V MEAN VALUE OF TASKS ACCOMPLISHMENT TIME, ERROR, ACTIONS CARRIED OUT CLASSIFIED BY SEARCH METHOD

Search Method	Conditions	Time	Errors	Actions
Sender 5 Tasks	Control	67.35	1.04	2.01
	LinearVis	41.95	0.71	2.55
Date 5 Tasks	Control	69.36	0.92	2.81
	LinearVis	36.08	0.52	1.81
Subject 1 Task	Control	80.67	2.13	3.73
	LinearVis	42.13	1.07	1.69
Attachments 1 Task	Control	94	1.33	5.13
	LinearVis	51.40	0.80	2.87

completion rate as well as users' satisfaction when compared to the standard email client. Thus, the stated hypotheses for effectiveness and users' satisfaction were approved.

Table V shows the mean value of each efficiency parameter used in the experiment classified by email properties used to find messages. Such classification can help to identify the usefulness of each component in the experimental condition. Table V shows that the dateline in LinearVis II helped users to accomplish most experimental tasks with reduced time, errors and number of actions in comparison with the standard email. Reducing the length of the dateline to be composed of months rather than days as in the previous version (i.e. LinearVis) helped to find messages of the current and previous years with fewer efforts than the standard email client. Furthermore, observations showed that grouping showed that users found locating messages by date using the dateline is significantly easier than the typical sorting process.

Senders' list in LinearVis II differs from the one in the previous version (i.e. LinearVis) in one aspect which is the interactivity where users can select and look up senders. Experimental results showed that it helped users accomplishing most of the experimental tasks with reduced time and errors when compared to the standard condition (see Table V). Moreover, statistical results showed that users found locating email messages using the senders' list is significantly easier than the conventional way used in the standard email. However, number of actions required to find email messages using the senders' list in LinearVis II was increased when compared to the standard email. This is because of the training sessions given to users prior the experiment were not adequate to make them familiar with the provided names and addresses since most users did not exploit senders sorting in the list. Users' performance in LinearVis II was further analysed and compared based on the type of the experimental tasks.

The results showed that the tasks in which users were required to use the senders' list were performed with increased time and errors when compared with the tasks in which they were required to use the dateline (see Table V). Such comparison is possible as the number of tasks is the same and tasks were performed equally in LinearVis II, too. Consequently, unfamiliarity with the provided names and addresses has also affected users' performance in terms of time and errors when locating messages by senders in LinearVis II although they were significantly reduced when compared to the standard email. This issue is most likely will be resolved when the

familiarity of names and addresses increase or using users' personal email data.

Experimental results also showed that presenting the recipients of email messages in the temporal view of LinearVis II helped users to accomplish experimental tasks with reduced time, error and number of actions when compared to the standard email. Most users also found that the identification of To, CC in LinearVis II is easier than the standard email. This result was statistically significant. Since the temporal view was found effective for presenting such information it can also be utilised to present more email data which can also improve the accessibility to email messages such as threads. Furthermore, instant subject search in LinearVis II helped users to complete the last experimental task with reduced time, errors and number of actions in comparison with the standard email. Placing the textbox in the main view of LinearVis II reduced the number of actions required to complete the task and hence time and errors were reduced, too. Statistical results demonstrated that it was significantly easier than the conventional subject search used in the standard email.

One of the novel components in LinearVis II is the attachment panel. It helped users finding attached files by senders with dramatically reduced time, errors and number of actions when compared to the standard email in spite of the recalling difficulties observed during the experiment due to the unfamiliarity with such new feature. Satisfaction results indicated that finding attachments in LinearVis II is significantly easier than the standard email. The classification of attachments according to files types was found very effective for accessing the required files. Hence, the size of application icons in this panel can be reduced to add more files types such as video and image files.

Statistical results showed that tasks accomplishment time and errors were significantly reduced in LinearVis II when compared to the standard email. Thus, the hypothesis regarding the efficiency was confirmed in terms of time and errors. Number of actions carried out to perform experimental tasks in LinearVis II was also reduced when compared to the standard email. However, this difference was not statistically significant. Nevertheless, statistical results showed that number of actions carried was significantly reduced in LinearVis II when the experimental results that used senders' details were excluded. Thus, the hypothesis regarding the efficiency was initially rejected in terms of number of actions and most likely will be confirmed when users become more familiar with the provided email data. Users' email data was not used in the experiment for two reasons: first, to ensure that the number of messages used in the experiment is the same hence the usability metrics will be measured far from other effects. The second reason is the difficulty of finding adequate number of high volume email users for the experimental programme.

XI. CONCLUSION

This paper described an empirical study which was carried out in order to investigate the usability of browsing email data. An experimental email tool, called LinearVis II, was developed to help users browsing email messages easily. It

was composed of multi coordinated views: dateline, senders' list, main view, temporal view and attachment panel. The dateline was designed to help users navigating through email messages in the inbox by date easily. Senders' List presented the most active senders within a month to help users finding messages by senders as the relationship of email users with other people changes over the time. Senders look up feature was implemented in the senders' list to find messages sent by less active senders easily. Email messages were displayed in the main view of LinearVis II classified by days and the recipients were presented in the temporal view. The attachment panel was designed to help users accessing attached items easily at glance. A comparative usability evaluation was conducted between the proposed email tool and a typical email client. The results were based on effectiveness (i.e. tasks completion rate), efficiency (i.e. tasks accomplishment time, errors, number of actions carried out) and users' satisfaction. Experimental results indicated that LinearVis II helped users finding email messages with significant improvement in effectiveness, efficiency and users satisfaction when compared to the typical email client. However, number of actions required to find email messages using the senders' list in LinearVis II was increased when compared to the standard email. This is due to the unfamiliarity of users with the provided names and addresses since most users did not exploit senders sorting in the list.

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