

Email Threads: A Comparative Evaluation of Textual, Graphical and Multimodal Approaches

Saad Alharbi, Dimitrios Rigas

Abstract— Email threads were implemented by enormous number of studies in order to improve the efficiency of email clients. Nevertheless, contextual information about messages in the threads was somewhat neglected by most of these studies. This paper describes an empirical study carried out to investigate into how extent can such information be implemented in email threads. Furthermore, this study aimed to investigate various ways of communicating this type of information. Therefore, three email threads approaches that presented various types of information in different ways were developed. Textual approach, which presented related messages with chronological and contextual information in the main view of the email client. Graphical approach, which presented related messages with chronological, relationships and contextual information in a temporal view. Multimodal approach, where threads presented in a similar way of the previous approach with some contextual information communicated aurally (i.e. non-speech sound). These approaches were tested comparatively with three independent groups of users. The results were analysed based on effectiveness (i.e. tasks completion rate and identification of threads information) and efficiency (i.e. tasks accomplishment time and errors rate). The results indicated that multimodal threads approach was more effective and efficient than the textual approach. The results also highlighted that the large scale of graphically presented information in the graphical approach has negatively affected its effectiveness when compared to the textual approach especially with complex email threads. However, communicating messages information through two channels (i.e. visual and auditory channels) in the multimodal approach helped to reduce the graphical overload and hence significantly improved the usability when compared to the graphical approach.

Keywords— Browsing, Effectiveness, Efficiency, Email, Graphical, Threads, Usability, Visualisation.

I. INTRODUCTION

With the diversity of using email, inboxes have become overloaded with the large volume of email messages [1-3]. Many design ideas and techniques were employed by numerous studies to improve the usability of email clients. One

of the most important features that were implemented in email to reduce the complexity of inboxes is threads (i.e. email conversation). Email threads were defined as a group of email messages related by the reply function. The benefits of employing threads in email clients have been well documented in [4] [5]. Generally, two types of information were incorporated in various ways in most of the studies that used this technique to improve email clients. First, relationships between messages where users can decide which messages are reply to which message. Second, chronology of messages where it can be decided which messages were sent before a particular message. However, contextual information about email messages such as the status and priority of messages within the threads have been somewhat neglected. This type of information can be critical depending on users' purposes and hence the absence of such information can lead to serious usability problems. Let's assume that a user would like to access the email message that contains an attachment within a thread. This task can become difficult with the absence of such information especially with threads containing large number of messages because most messages need to be opened to find the required one. The same scenario can be assumed for different information such as the priority and status of email messages.

This paper describes an empirical study carried out to investigate into how extent can contextual information about email messages be incorporated into threads. In addition, this study aimed to investigate various ways of communicating such information to users. Therefore, three experimental threads approaches (i.e. Textual, Graphical and Multimodal), which presented contextual information alongside other types of information in different ways, were implemented in an experimental email client called LinearVis II. The design of these approaches is described in this paper. The paper also describes the empirical study and highlights the obtained results. Finally, it concludes with highlighting the findings of this experimental work.

II. RELATED WORK

A. Email Threads

The idea of email threads was inspired from online conversation [6]. For example, Usenet newsgroups discussion [7, 8] and chat programmes [9]. However, email threads is

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defined as the reply relationship between a group of email messages [10]. Many studies were carried out in visualising email threads. For instance, Rohall et al developed three visualisation techniques and combined them in order to enhance the email inbox [11, 12]. These visualisation techniques depend on message threads, time and content of the email messages respectively. In the thread visualisation, all messages that are related by the reply function are shown as connected tree. The relationships between messages senders with the recipient 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 and messages sent by the company manager were coloured in red. One of the limitations of this work is that the relationships between messages senders and the recipients were only presented in the threads view. Other useful information can be communicated in graphical threads approaches such as relationships between messages where users can decide which messages were sent as reply to a particular message. Contextual information about messages such as attachment, priority and status can also be useful when presented in such information.

Sudarsky and Hjelsvold developed an email tool that visualised messages based on a hierarchal nature of domain names in e-mail addresses such as COM and EDU [13]. This approach contains two basic views: a tree generated from the domain names and temporal view which presents email messages. A thread feature was implemented in this tool to display related messages of a selected node from the tree view in the temporal view. However, threads in this work are presented for a specific senders based on the user selection as well as the presented thread occupies the temporal view where unrelated messages cannot be presented at the same time. The results of the user study showed a significantly improved users performance when locating messages, as well as improved overall preferences [13]. However, this study was brief and informal.

Venolia and Neustaedter pointed out that email clients would be more useful if conversation threads were used as the main display for email clients [5]. They presented a mixed-model visualisation that shows the sequence of email messages and reply relationships among the messages of conversation. Two types of information were communicated to users in this model: sequence of messages (i.e. chronology) and relationships between messages. However, contextual information regarding messages in the threads was not provided. In addition, the main view was totally dedicated to present the relationships between messages in a particular thread when it is selected from the sequential view.

Kerr developed a visualisation technique called "Thread Arcs" that shows the reply relationships between messages based on seven key qualities: chronology, relationships, stability, compactness and attributes highlighting, scale and interpretation [14]. Related messages are connected with arcs and displayed chronologically. It was compared with the

existing thread visualisation approaches such as tree diagram and tree table visualisations and it showed an advantage over them [14]. Thread Arcs was used in the reinventing email "Remail" project [10]. Contextual information about threads such as time shading, users' own contribution was provided in this approach. However, contextual information about messages was not provided.

"EzMail" is a multi-view email visualisation that displayed messages as components of threads in order to provide contextual information and conversational history [15]. All threads and messages in a selected folder can be displayed in the main view in a similar way of representative email clients. However, messages without threads grouping are presented only when the list is resorted by date or sender. This tool was compared with a traditional textual thread and it has been found more usable and preferred by users [15].

Perer and Shneiderman stated that threading messages by subject lines and reply relationships does not reflect users behaviour [16]. Therefore, they developed a thread visualisation that portrayed users participated in a conversation in addition to the time of sending messages [16]. Inner-Circle is an email tool that organises email conversations (threads) in a people centred way [17]. It was composed 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 the last month. Conversations among group of selected people only can be presented in the conversational view. 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, contextual information about messages was not fully addressed. This type of information should not be neglected when visualising email threads as users typically use such information to locate messages [18].

B. Auditory Metaphors in Email

Incorporating the auditory metaphors with graphical email approaches is still in its infancy. However, a small number of studies investigated the possibility of communicating email data aurally using speech and non-speech sounds. For instance, Hudson and Smith proposed an email tool that use non-speech sound to present important properties of e-mail messages into a short sound for example, user can know the category (read, unread, replied) of an email message without opening it [19]. Furthermore, Rigas performed a series of experiments to investigate the use of various types of sound when browsing e-mail data. Rigas and Memery stated that there is a risk when using information hiding for reducing the graphical complexity which could be critical depending on what users want [20]. They pointed out that using a combination of different types of sounds (speech, non-speech) for conveying e-mail data instead could reduce this complexity [20]. The results of their experiments proved that auditory stimuli such as Earcons, auditory icons and speech can be used to communicate the

hidden information in e-mail data [21]. In these experiments, they examined whether the users could recognise the e-mail categories using compositional sound. Users were able to recognise the categories of e-mail using 2 seconds of compositional sound. as the results were very motivated, they performed further experiments in order to investigate whether users can recognise the e-mail categories together with other types of information such as status, priority and the presence or absence of attachments [20]. Status (unread, replied, forwarded) of the e-mail message was communicated using stereophonic sound, the presence of attachment with the e-mail message was communicated using an auditory icon, the priority of the e-mail message was communicated using the repetition of electronic tones and the subject of e-mail message was communicated using speech sound [20]. These sounds were played to users and they were asked to identify the properties of email messages from these sounds. The results of these experiments showed that users could differentiate one sound from other and could recognise e-mail message properties successfully[20].

Our literature survey showed only one study that investigated the synergic use of audio and visual metaphors in browsing email data [22]. Two browsing techniques were developed in this empirical study: one for browsing simple e-mail data and the other for browsing complex data. In the simple technique, colours were used for communicating specific types of information where the sound used for communicating the identity of users. Sender, recipients and users that e-mail copied to them were communicated using rhythm. In the complex technique users were able to selects an e-mail message with its associated subject and the tool presents all the information in an audio-visual way. Number of e-mail messages received was communicated using audio stimuli besides the identity of users (sender, recipients). The results of using both techniques showed that users were able to understand the auditory stimuli [22]. Although the graphical browsing of e-mail data has been added in these experiments it has not enhanced to organise the e-mail inbox and the performance of the users has not been considered. The results of the experiments conducted by Rigas were interpreted into design guidelines for browsing email data aurally [23]. One of the most important derived guidelines that auditory message should have starting point, a main body and an ending point. Furthermore, Simultaneous use of different types of auditory stimuli should be synchronised with visually displayed information [23]. Moreover, the results of many studies such as [24-30] showed that the usability of traditional user interfaces in different problem domains can be improved by incorporating auditory metaphors.

III. EXPERIMENTAL PLATFORM

In order to conduct the experimental study, three types of email threads approaches (i.e. Textual, Graphical and Multimodal) were designed and embedded into LinearVis II (i.e. an experimental email tool). Related email messages were

TABLE I
THE WAY OF PRESENTED CONTEXTUAL INFORMATION IN EACH EXPERIMENTAL CONDITION

| Information | Conditions | | |
|----------------------------------|------------|-----------|---------------|
| | Textual | Graphical | Multimodal |
| Messages sent by the same sender | × | Colours | Colours |
| Messages sent on the same day | × | Colours | Colours |
| Messages Status | Text | Colours | Colours |
| Attachments | Icon | Colours | Auditory Icon |
| Priority | Icon | Colours | Earcon |

Fig. 1 A collapsed thread in the textual approach

grouped using ConversationID and ConversationTopic properties used in MS outlook APIs. Various types of information were provided in each approach. Table I shows the method used for presenting contextual information about messages in each approach. The graphical representations used in the graphical and multimodal approaches were produced using ActionScript 2.0 in Macromedia Flash MX. XML language was used to allow the communication between the experimental platforms (i.e. graphical and multimodal approaches) and the produced flash movies. These approaches are described in more details in the following sections.

A. Textual Threads

Fig.1 shows that threads are presented in this type of interface textually in the main view within all email messages. Two types of threads information (i.e. chronology and contextual) are presented in this approach. Relationships between messages were not provided in order to reduce the complexity of the inbox. Thus, questions 1 to 6 can only be answered in this approach. If an email message is a part of a thread, an arrow icon will be displayed beside its subject (see Fig.1). All messages in a thread can be presented by clicking on this icon. All email messages under the selected thread will be shifted down to leave the required space for displaying the thread's messages (see Fig.1). Also, the arrow icon will be changed to an arrow indicating up. Fig.1 shows that messages in a thread are presented indented to the right to distinguish them from unrelated email

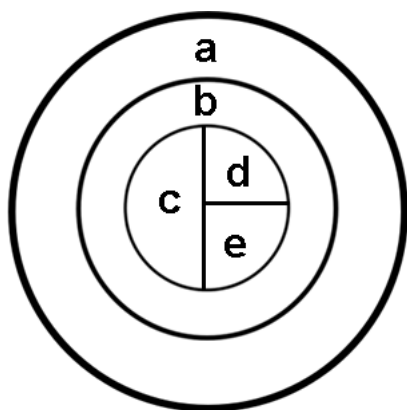


Fig. 2 graphical threads layout

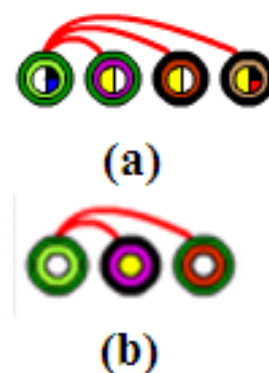


Fig. 3 A selected email thread in (a) the graphical approach (b) multimodal approach

messages presented in the same day chunk. The properties of email messages such as subject, attachment and priority in a thread are presented in a similar way of representative email clients (see Fig.1). This can help users to find out contextual information regarding each message in the thread.

Moreover, messages in a thread are displayed in a chronological order where the message presented after the selected one is the latest and the last message presented within the thread is the oldest. This way of presentation helps users understanding the arrival order of each message in the thread for example users can decided which messages were sent after and before the selected one. The relationships between messages are not shown in this type of threads. For instance, users cannot decide which email message is a reply to the other. This type of information was hidden from the users' view in order to avoid the complexity of the inbox. However, the root message, which is the first message in the thread, can be identified by the subject where it does not contain the part "Re:". Furthermore, messages in a thread can be re-hidden by clicking on the arrow icon again. The presented email messages in the main view will be shifted up to return to their primary position as well as the arrow icon will be change to indicate down.

B. Graphical Threads

This approach was designed to be presented in the temporal view of LinearVis2. The recipients of email messages were presented graphically in order to save an adequate area to display this type of threads. All types of information were provided which are: chronology, relationships and contextual. An icon, which contains three dots above each other with different colours, was designed to facilitate the identification of messages contained in a thread from the main view. For instance, if an email message is a part of a conversation this icon will be presented alongside the subject. By selecting an email message from the main view, the entire thread will be presented above the recipients in the temporal view in a similar way of THREAD ARCS (see Fig.3a). However, in our proposed graphical threads contextual information about messages such as the status, priority and the existence of attachment is presented to users at glance where it is not presented in THREAD ARCS. Table I shows how such

information was presented in this approach. Fig.3a shows that email messages in a thread are presented by circular icon. This icon was used to communicate the properties of each email message graphically where each icon was divided into three nested circles. Fig.2 shows the layout of messages icons in threads in this approach. The outer circle was used to communicate the person who sent the message. Messages sent by the same person within a conversation are filled by the same colour in this part of the icon. This can help users indentifying number of people participated in the conversation. For example, Fig.3a shows two persons only participated in a conversation composed of four messages. The intermediate circle was used to communicate the time messages were sent on. Messages sent on the same day are filled by the same colour in this part of the icon. For instance, all messages in the conversation shown in Fig.3a were sent in different days. The colours used in the outer and intermediate circles are automatically generated by the tool where they cannot be overlapped. The inner circle was divided into two semi circles (see Fig.2). In THREAD ARCS, new email messages added to the thread can be easily miss- noticed especially with large threads. Therefore, the first semi circle, which is located in the left side, was used to communicate whether the email message was read or not in order to facilitate the identification of new messages in threads. Similarly, colours were used to communicate such information where unread messages are filled yellow in this part of the message otherwise white colour is used. For example, the conversation shown in Fig.3a contains three unread messages and one read. The second semi circle was used to communicate priority of email messages and existence of attachments. The upper part of the semi circle used to communicate whether the email message contains attachments. This part of the message icon will be filled black if the email message contains attachments or white if it does not. Fig.3a shows that two email messages in the thread contain attachments. The filled colour of the lower part communicated to users whether the email message is important (displayed in red) and unimportant (displayed in blue). White colour was used to show that the priority of email message was not specified. The conversation shown in Fig.3a contains one email message with high priority and one email message with low priority.

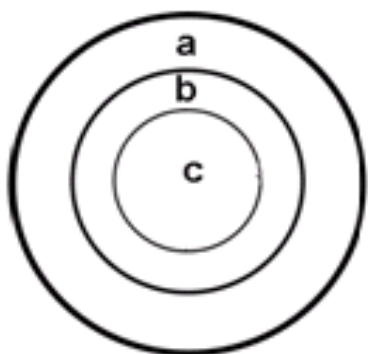


Fig. 4 Multimodal threads layout

Chronology of email messages within a thread is presented using their position in a similar way of THREAD ARCS where the first circular icon in the left represent the oldest message in the thread and the one located in the far right is the latest. Furthermore, the relationship between messages is presented with arch in a similar way of THREAD ARCS where each message connected with its parent by an arc. For example, all email messages in the conversation shown in Fig.3a are replied to the root message (i.e. the one located in the far left).

C. Multimodal Threads

Email messages are presented in the multimodal thread approach in a similar way of the graphical approach. The main aspect that differentiates it is that some information of email messages in the thread is communicated aurally in order to reduce the visual load and the complexity of the thread. Table I shows the way of presenting each property in this approach. Fig.4 shows the layout of messages icon used in this approach. The dividing of the inner circle in the messages icon was removed and has become a complete circle. The status of email messages (i.e. read, unread) is only presented in this part of the messages icon. This is more likely helps users identifying new messages easier than graphical approach. Moreover, the area used to communicate information in other circles such as the people participated in a thread was increased as the information communicated visually was reduced (see Fig.4).

Fig.3b shows a thread contained three (i.e. one unread and two opened) email message sent by two persons. The existence of attachment in email messages and the priority (i.e. high and low) are communicated with non-speech sound when the mouse cursor moves over the message icon. A sound similar to the 'stapler' was used to communicate the email message that contains attachments. This sound will not be played if the email message does not contain attachments. The duration of this sound was 0.50 seconds. Furthermore, the priority of email messages was communicated using earcons based on the guidelines in [31, 32]. Five notes with 0.1s delay using Celesta were used to communicate high priority email messages. In order to avoid users' confusion, different number of notes, delay and instrument were used to communicate low priority messages. Three notes with 0.4s delay using acoustic piano were used to represent low priority. The duration of each note was 0.15s. If the priority of an email message was not

TABLE II
EXPERIMENTAL TASKS

| Task No | Description |
|---------|--|
| T1 | Finding a thread by date which all its message contain attachment |
| T2 | Finding a thread by date which does not contain attachment |
| T3 | Finding a thread by sender that contains two unread messages |
| T4 | Finding a thread by sender that contains more than two unread messages |
| T5 | Finding a thread that all its messages sent on the same day and contains three messages sent by the same sender |
| T6 | Finding a thread by date which contains an unread message with attachment and unread message with attachment and low priority |
| T7 | Finding a thread by date which contains a message with attachment, a message with low priority and a messages with high priority |
| T8 | Finding a thread by sender which contains an unread message with attachment and high priority and a message with attachment and low priority |

assigned, none of these sounds will be played. If an email message contains attachments and has been given a priority, the sound used to communicate attachment will be played first and then the priority notes.

As mentioned earlier, new messages added to the thread are most likely dismissed by users especially in large conversations. Therefore, number of new messages in a thread is communicated aurally when a related email message is selected from the main view alongside the graphical presentation described above. This type of information was communicated to users using rising pitch notes (range 1 to 3) based on the guidelines in [33, 34]. A note is played when the conversation contains one new email message and two notes are played when it contains two new email messages. Three notes are played when the conversation contains more than two new messages. For example, one note will be played when the email message related to the conversation shown in Fig.3b is selected. All notes were played using organ with 0.1s delay and 0.3s duration.

IV. EXPERIMENTAL DESIGN AND PROCEDURE

The aim of this experiment is to investigate the possibility of presenting contextual information about email messages in email threads. This experiment was also designed to investigate usability aspects of presenting email threads textually in the focus area of the inbox, graphically and using multimodal metaphors. Therefore, three experimental conditions (i.e. textual threads, graphical threads and multimodal threads) were tested in this experiment. The same email inbox that contained 921 real email messages was used in the three experimental conditions. The oldest email message was sent on 06/02/06 where the most recent was sent on 13/10/08. These conditions were tested independently (i.e.

between-subject design) by three groups, each group tested one experimental condition. Forty five users, fifteen in each group, were asked to participate in this experiment (see Section VI for more details about users' profile). This methodology was used in order to avoid the learning effect, users' confusion and tiredness. Eight experimental tasks were designed in order to control users' performance during the experiment and to test the usability of each condition. Table II shows the experimental tasks used in the experiment. In each task, users were asked to find an email thread with the provided relevant information. Users were required to find email threads by date beside other contextual information about email messages such as messages sent by the same sender or messages contain attachments in four experimental tasks (see Table II). Also, they were required to find threads by sender beside other contextual information in four experimental tasks. The complexity of the last three experimental tasks (i.e. T 6, T7 and T8) was increased by increasing the required information in the threads to test users' performance when browsing complex and large email threads under the three experimental conditions (see Table II).

Seven questions regarding the contextual information of email messages in threads were set to investigate users' understanding of the proposed threads presentations. In order to avoid learning effects and users' tiredness, they were rotated on experimental tasks. A combination of four questions was required to be answered after performing each of the first six experimental tasks (i.e. T1, T2, T3, T4, T5 and T6) and a combination of three questions after each of the last two tasks (i.e. T7 and T8). Four training session, each session lasted one hour, were given to each group of users prior the experiment in a typical computer lab. Users were introduced with the concept of email threads as well as how to use the experimental platform. They were also required to carry out training tasks apart of the tasks used in the experiment. The experiment was conducted with the users of each group together in the same lab.

V. HYPOTHESES AND VARIABLES

The main hypothesis of this experiment is that the usability of textual, graphical and multimodal threads is different. The usability of each condition was measured by taken into account the effectiveness and efficiency. The dependant variables used in this experiment were classified according to these usability metrics. Effectiveness of each experimental condition was measured by considering tasks completion rate and identification of threads information. Moreover, tasks accomplishment time and error occurred whilst performing tasks were measured in order to test the efficiency of the three experimental conditions. The main hypothesis was decomposed to more specific hypotheses to investigate the usability of each experimental condition and classified based on the usability metrics used. These hypotheses are:

1. Effectiveness of textual, graphical and multimodal approaches should be different in terms of tasks completion and identification of messages data

2. Efficiency of textual, graphical and multimodal approaches should be different in terms of tasks accomplishment time and errors
3. Graphical threads should be more effective than textual threads in terms tasks completion and identification of messages data
4. Graphical threads should be more efficient than textual threads in terms tasks accomplishment time and errors
5. Multimodal threads should be more effective than textual threads in terms tasks completion and identification of messages data
6. Multimodal threads should be more efficient than textual threads in terms tasks accomplishment time and errors
7. Multimodal threads should be more effective than graphical threads in terms tasks completion and identification of messages data
8. Multimodal threads should be more efficient than graphical threads in terms tasks accomplishment time and errors

VI. SAMPLE

Forty five users, three groups of fifteen, were asked to participate in the experiment. All of them were undergraduate students doing a bachelor degree in computer science. They were required to fill pre-experimental questionnaire in order to gather information about their email habits and experience. The results showed that all of them had no experience in using threads. Furthermore, the majority of the sample aged between 18 to 25. Also, the majority of the sample checked their emails several time a day.

VII. RESULTS

Users' performance was fully recorded in each experimental condition. These recordings were analysed independently in order to measure tasks accomplishment time and errors carried out. Answer sheets of the questions that were asked after each experimental task were compiled to measure the level of users' identification of threads information. This data was analysed independently based on effectiveness and efficiency.

A. Effectiveness

1) Tasks Completion Rate

A critical time was derived for each experimental task to find out whether it was completed or not. Users who took longer than this time to complete a task were considered as not to have completed the task as well as those who did not find the required email thread successfully. Fig.5 shows the percentage of users who completed each experimental task in the three experimental conditions. The percentage of users completed the first four experimental tasks is swung among all experimental conditions. For example, the percentage of users

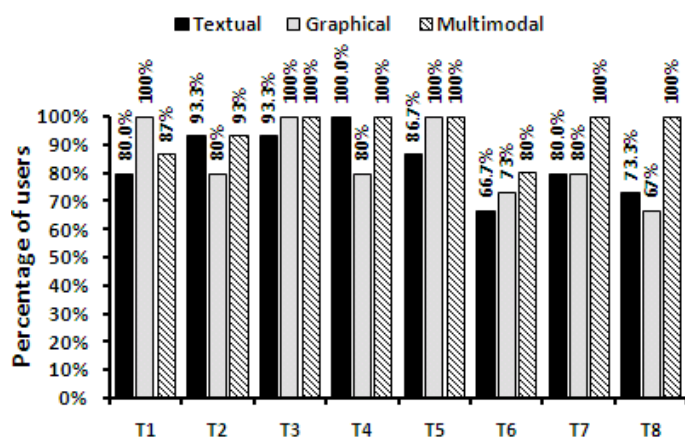


Fig. 5 Users who successfully completed each task

who completed the first experimental in the graphical condition was the highest when compared to the textual and multimodal conditions whereas the second experimental task was completed with the highest number of users in the textual condition in comparison with graphical and multimodal conditions. In tasks 3 and 4, users were required to find threads by the number of unread messages. All users completed both tasks in the multimodal condition as this type of information is communicated to users by earcons when a relevant email message is selected since they did not need to visit each message in the threads to complete such tasks. In contrast, not all users could complete both tasks in the textual and graphical conditions. Fig.5 shows that presenting the contribution of people in the threads and messages sent on the same day graphically helped more users to complete task 5 in the graphical and multimodal conditions when compared to the textual. As mentioned previously, the complexity of the last three experimental tasks (i.e. T6, T7 and T8) was increased by increasing the number of required information in the threads (see Table II). The percentage of users who completed these tasks in the textual and graphical conditions is somewhat similar (see Fig.5). This is because of users were visually overloaded in the graphical condition as all information was presented by colours. In contrast, communicating some information aurally to reduce the visual load helped to complete these tasks in the multimodal condition with remarkably higher percentage of users when compared to the textual and graphical conditions.

Fig.6 shows the percentage of tasks completed by all users and the overall percentage of users who completed all tasks in the three experimental conditions. It shows that the percentage of tasks (i.e. five tasks) completed by all users in the multimodal condition is considerably higher when compared independently to the textual and graphical conditions. Moreover, three experimental tasks were completed by all users in the graphical condition whereas only one experimental task was completed by all users in the textual condition. Fig.6 also shows that the overall percentage of users (i.e. eleven users) who completed all tasks in the multimodal condition is notably higher when compared to the textual and graphical conditions. Furthermore, about half of

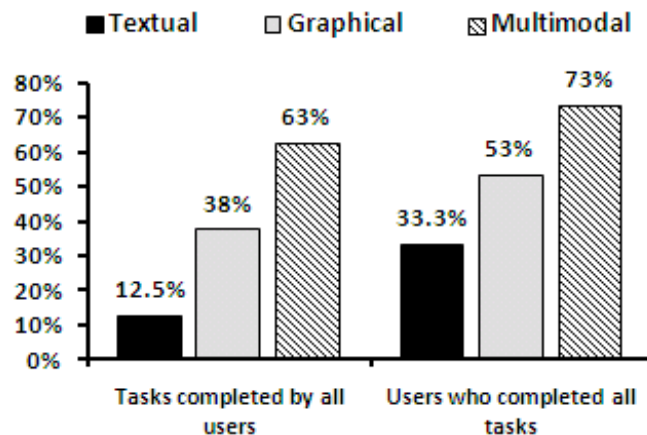


Fig. 6 Overall tasks completion rate

the users completed all tasks in the graphical condition while only five users have completed all tasks in the textual conditions. In fact, the multimodal presentation of email threads were found the best conditions in terms of tasks completion and the textual was found the least effective conditions in terms of tasks completion. Chi-square was performed on the number of users who completed all tasks in order to test the significance of this difference. The results indicated that tasks completion rate is not significantly different among the three experimental conditions ($\chi^2 = 5.99$, $df=2$, $cv=5.99$, $p>0.05$). In order to investigate the most effective threads approach in terms of tasks completion, experimental conditions were independently compared to each

TABLE III
TASKS COMPLETION STATISTICAL RESULTS, SIGNIFICANT RESULTS DISPLAYED IN BOLD

| Conditions | Statistical results |
|-------------------------|--|
| Textual Vs Graphical | ($\chi^2 = 1.22$, $df=1$, $cv=3.84$, $p>0.05$) |
| Textual Vs Multimodal | ($\chi^2 = \mathbf{4.82}$, $df=1$, $cv=\mathbf{3.84}$, $p<\mathbf{0.05}$) |
| Graphical Vs Multimodal | ($\chi^2 = 1.30$, $df=1$, $cv=3.84$, $p>0.05$) |

other. The results are shown in Table III. However, the results indicated that multimodal condition is significantly more effective in terms of tasks completion when compared to the textual condition. Also, the results indicated that the effectiveness of the graphical condition fluctuated between the multimodal and the textual approaches where the graphical presentation of threads in a temporal view (i.e. off the focus area) helped to increase the tasks completion rate. At the same time, visually overloading users with colours decreased tasks completion rate to a level near to the textual condition.

2) Identification of Threads Information

Users' answers of the questions asked after performing each experimental task were analysed in two ways. First, they were analysed according to the experimental tasks in order to investigate the effect of the tasks and the type of information presented to users in the threads. The total number of correct answers in each experimental task was calculated for each user. The mean value of correct answers for each experimental task was also calculated in the three experimental conditions.

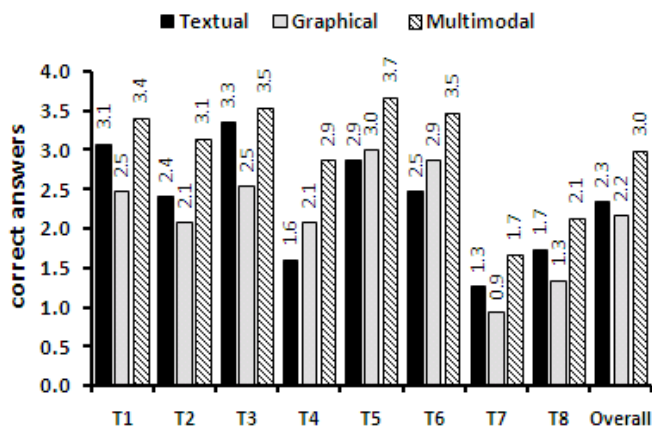


Fig. 7 Correct answers classified by tasks

Fig.7 shows that the number of correct answers for all experimental tasks was the highest in the multimodal condition when independently compared to the textual and graphical conditions. It also shows that the difference between the graphical and textual conditions in the mean value of correct answers was varied in most experimental tasks.

This is due to the nature of the tasks and the complexity of the required threads. For instance, the number of messages in the required threads in the first three experimental tasks was not high (i.e. about two messages). Therefore, the mean value of correct answers in this type of tasks was higher in the textual condition when compared to the graphical condition as messages information was presented in the conventional way used in representative email clients where users had difficulties recalling colours in the graphical condition (see Fig.7). Fig.7 shows that the reduction of graphically presented information and the increase in the areas dedicated to communicate graphical information helped users answering more questions correctly in the multimodal condition after performing the same tasks when compared to the textual and graphical conditions. Furthermore, the observation of users' performance showed that the majority of users who used the textual condition mixed between the messages contained in the threads and messages displayed in the same day chunk especially when the number of related messages in threads is increased. Consequently, the mean value of correct answers in tasks four, five and six was higher in the graphical condition in comparison with the textual condition as most of them had difficulties identifying the number of email messages in the required threads and hence answering the rest of questions incorrectly. In contrast, the mean value of correct answers in the same tasks was higher in the multimodal condition when compared to the graphical condition (see Fig.7). The required threads in the last two experimental tasks communicated large number of information for example at least one email property (i.e. attachment, priority or status) was presented in each message. Fig.7 shows that the number of correct answers in these tasks was dramatically reduced in the graphical condition when compared to the textual and multimodal conditions. This is because the large scale of graphically presented information in this approach complicated the identification of threads

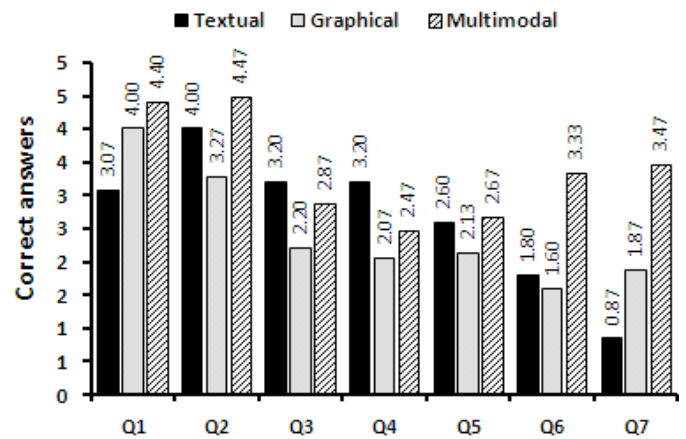


Fig. 8 Mean value of correct answer of each question

information. In fact, information presented in the multimodal condition was found the most identified by users in spite of it is presented in a conventional way in the textual way. Second, users' answers were also analysed according to the seven questions to investigate the role of the method used to communicate messages information in each experimental condition. The mean value of correct answers for each question was calculated in the three experimental conditions. Fig.8 shows that number of related messages in threads was identified easily in the graphical and multimodal conditions when compared to the textual condition. This is because threads are presented in the main view of the textual condition with unrelated email messages where the majority of users' were observed mixing between messages in the threads and unrelated ones. Fig.8 shows that the number of correct answers in the second question, in which users were asked about the number of unread messages, was the lowest in the graphical condition when compared to the multimodal and textual condition. This is due to the small area used to communicate such information. On the other hand, number of unread messages in threads was identified more easily in the multimodal condition when compared to the textual condition as such information was clearly presented in a larger area in comparison with the graphical condition. The priority of related email messages in threads (i.e. questions 3 and 4) was more identified in the textual condition when compared to the graphical and multimodal conditions because users were more familiar with the icons used to communicate such information in the textual condition than the graphical and multimodal conditions (see Fig.8). However, non- speech notes used to communicate such information in the multimodal approach was more identified than the graphical representations used in the graphical approach. Identification of the auditory icon used to communicate the existence of attachments in messages in the multimodal condition was found nearly similar to the conventional way used in the textual condition. Also, this type of information was least identified by users in the graphical condition where they had recalling difficulties especially with the large scale of graphically presented information. Fig.8 shows that identifying people contribution in threads was the

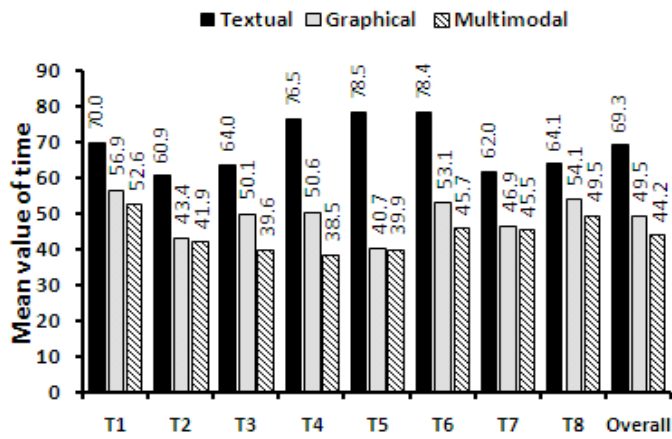


Fig. 9 Time taken to accomplish each experimental task and the overall tasks accomplishment time

easiest in the multimodal condition when compared to the textual and graphical conditions. As messages icons were visually crowded in the graphical approach, identifying people contribution in threads was nearly similar to the textual condition in spite of it was presented in a similar way of multimodal condition. Fig.8 shows that number of messages sent on the same day was identified easier in the graphical condition when compared to the textual condition. Similarly, reducing the amount of information graphically communicated to users led to a considerable increase in the number of correct answers in the multimodal condition.

The overall mean value of correct answers was calculated in the three experimental conditions. Fig.9 shows that the overall mean value of correct answers in the multimodal condition was the highest when compared to the graphical and textual conditions. It also shows that the mean value of correct answers of the graphical and textual conditions was nearly similar. One-way Anova was applied on in order to test this difference. The results showed that the three experimental conditions are not significantly different in terms of number of correct answers ($F(2, 21) = 2.82, cv = 3.46, p > 0.05$). This is most likely because of the similarity between the graphical and textual conditions. Therefore, t-test was performed on the number of correct answers in order to investigate the most effective threads approach. The results are shown in Table IV. The results indicated that messages information communicated to users in the multimodal condition was significantly more identified than textual and graphical conditions. Thus, multimodal threads approach was the most effective condition in terms of number of information identified by users. Conversely, graphical representations used in the graphical approach were the least effective method to communicate threads information.

B. Efficiency

1) Tasks Accomplishment Time

Fig.9 shows the mean value of time taken to accomplish each experimental task in the three experimental conditions. It can clearly be noticed that all experimental tasks were accomplished with considerably reduced time in the graphical

TABLE IV
THREADS IDENTIFICATION STATISTICAL RESULTS, SIGNIFICANT RESULTS
DISPLAYED IN BOLD

| Conditions | Statistical results |
|-------------------------|---|
| Textual Vs Graphical | ($t_{14} = 1.22, cv = 1.76, p > 0.05$) |
| Textual Vs Multimodal | ($t_{14} = \mathbf{1.76}, cv = \mathbf{1.76}, p = \mathbf{0.05}$) |
| Graphical Vs Multimodal | ($t_{14} = \mathbf{2.28}, cv = \mathbf{1.76}, p < \mathbf{0.05}$) |

and multimodal conditions when compared to the textual condition. This is most likely because users were overwhelmed by the large volume of presented email messages in the main view of the textual condition. In contrast, presenting email threads in the temporal view of graphical and multimodal conditions helped to lessen the complexity of the inbox and hence users could decide whether the thread was the required one or not at a glance. For instance, Fig.9 shows that users took longer time to recognise the required thread in the first task amongst the presented messages in the same day chunk when compared to the graphical and multimodal conditions. Furthermore, the time taken to complete task 5, in which users required to find threads by people contribution and chorology of messages, was dramatically reduced in the graphical and multimodal conditions when compared to the textual condition (see Fig.9). In the multimodal condition, users needed to move the mouse cursor over each email message in the thread in order to listen to messages information. Nevertheless, the time taken to complete most experimental tasks was nearly the same in graphical and multimodal conditions. The main reason behind this result is that they used almost the same approach to present email threads as well as users could easily identify the non-speech sounds communicated messages information in the multimodal condition. However, time taken to accomplish the tasks in which users required to find threads by the number of unread email messages (i.e. tasks 3 and 4) was noticeably reduced in the multimodal condition when compared to the graphical condition. This is mainly because of the rising pitch metaphors used to communicate number of unread messages in the multimodal condition helped users to identify the required thread from the main view without looking at the threads in the temporal view. Clearly, it also helped users identifying number of unread messages more easily than the common way used in the textual condition. Moreover, the mean value of time taken to complete the last three experimental tasks, in which the complexity of required threads was increased, was slightly reduced in the multimodal condition in comparison with the graphical condition. Meaning that, users' performance was affected by the large scale of visually presented information in the graphical condition.

The overall mean value of tasks accomplishment time was also calculated. Fig.9 shows that the textual condition required the highest time to complete all experimental tasks when compared to the graphical and multimodal conditions. Furthermore, the overall mean time take to complete all tasks in the multimodal condition was slightly lower than the graphical condition. One-way Anova was performed in order to investigate whether these conditions are significantly

TABLE V

TASKS ACCOMPLISHMENT TIME STATISTICAL RESULTS, SIGNIFICANT RESULTS DISPLAYED IN BOLD

| Conditions | Statistical results |
|-------------------------|---|
| Textual Vs Graphical | ($t_{14} = 6.28$, $cv=1.76$, $p<0.05$) |
| Textual Vs Multimodal | ($t_{14} = 7.77$, $cv=1.76$, $p<0.05$) |
| Graphical Vs Multimodal | ($t_{14} = 1.53$, $cv=1.76$, $p>0.05$) |

different in terms of tasks accomplishment time. The results indicated that they are significantly different ($F(2, 21) = 37.56$, $cv=3.46$, $p < 0.05$). In order to investigate the most efficient condition in terms of tasks accomplishment time, the three experimental conditions were statistically compared to each other using t-test. The results are shown in Table V. The results showed that the time taken to complete experimental tasks was significantly reduced in the graphical and multimodal condition when compared independently to the textual condition. Meanwhile, time taken to complete tasks in the multimodal condition was not significantly reduced when compared to the graphical condition. Thus, textual condition was found the least efficient condition in terms of tasks accomplishment time. Moreover, the efficiency of graphical and multimodal conditions was found almost the same in terms of tasks accomplishment time.

1) Errors Rate

Fig.10 shows the mean value of errors occurred whilst performing each experimental task in the three experimental conditions. It can be noticed that all experimental tasks were performed in the multimodal condition with the lowest errors rate whereas the highest errors rate occurred in the textual condition. Furthermore, errors rate in the graphical condition was unsettled during the experiment according to the type of tasks and threads. It reached to a similar rate of the textual condition in some experimental tasks and also reached to a level near to the multimodal condition in other tasks (see Fig.10). One of the most frequent errors that were observed when displaying email threads, especially in the first two experimental tasks, in the textual condition is slipping from the arrow icons. For example, the majority of the users made this error at least one time when carrying out the first experimental task. On the contrary, this type of errors was not observed in the graphical and multimodal conditions as threads were displayed in the temporal view by selecting a related message from the main view. Thus, the mean value of errors occurred whilst performing the first two experimental tasks was considerably reduced in the graphical and multimodal conditions when compared to the textual condition. However, errors rate in these tasks was almost the same in the graphical and multimodal conditions. Moreover, one of the errors that were observed frequently when performing the experimental tasks in the textual conditions is that not considering the selected message is a part of the thread. For instance, users selected an email thread contained two messages with attachments and the selected messages did not contain attachments when they were asked to find the thread that all its messages contain attachments (i.e. Task 1). Users were also

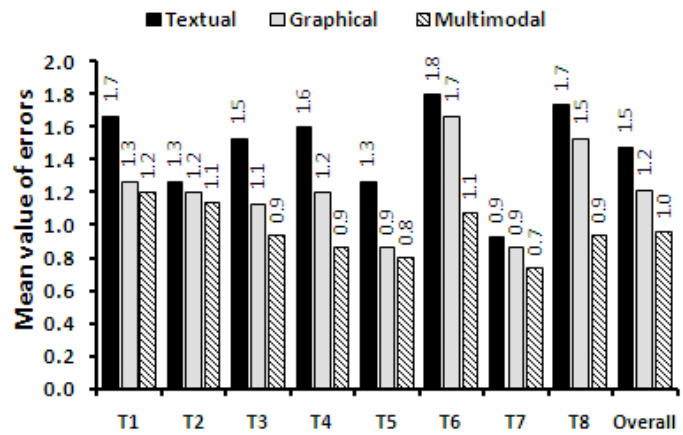


Fig. 10 Errors carried out whilst performing experimental tasks

observed repeatedly mixing between messages in the threads and unrelated messages whilst performing most experimental tasks in the textual condition especially with threads containing large number of messages. However, these errors were not observed in the multimodal and graphical conditions as threads were presented separately in a different view as well as number of related messages can clearly be identified through the number of messages icons.

Miss-noticing the required email threads was one of the most frequently occurred errors in the graphical condition. For instance, most users were observed in most experimental tasks searching for the required threads while it was selected. However, the auditory metaphors used in the multimodal condition helped users performing tasks without carrying out such errors. For example, the rising pitch notes helped users accomplishing the tasks in which they were required to find threads by number of unread messages (i.e. tasks 2 and 3) with dramatically reduced errors when compared to the graphical condition (see Fig.10). Moreover, users could perform the task in which they required to find a thread by people contribution and chronology of messages (i.e. task 5) with remarkably reduced errors in the graphical and multimodal conditions when compared independently to the textual condition (see Fig.10). However, errors occurred whilst performing this task in the multimodal condition was slightly reduced when compared to the graphical condition because of the expansion of the areas used to present graphical information in messages icons. One of the observed errors in both multimodal and graphical conditions is the mixing between high priority and low priority messages. For example, many users considered messages as high priority when listening to the low priority earcon whilst performing tasks in the multimodal condition and vice versa. This type of errors was noticeably increased in the graphical condition when the complexity of email threads was increased. For instance, although the number of errors in this condition was lower than the textual condition in most tasks but it was increased when carrying out the last three experimental tasks to a level near to the textual condition.

Fig.10 also shows the overall mean value of errors carried out in the three experimental conditions. The mean value of errors

carried out in the multimodal condition was dramatically reduced when compared independently to the graphical and textual condition. Also, experimental tasks were carried out with a reduced number of errors in the graphical condition when compared to the textual condition. One-way Anova was performed on this data in order to investigate this difference. The results indicated that the three experimental conditions are

TABLE VI
ERRORS RATE STATISTICAL RESULTS, SIGNIFICANT RESULTS DISPLAYED IN BOLD

| Conditions | Statistical results |
|-------------------------|---|
| Textual Vs Graphical | ($t_{14} = 1.79$, $cv=1.76$, $p<0.05$) |
| Textual Vs Multimodal | ($t_{14} = 4.34$, $cv=1.76$, $p<0.05$) |
| Graphical Vs Multimodal | ($t_{14} = 2.24$, $cv=1.76$, $p<0.05$) |

significantly different in terms of error carried out. ($F(2, 21) = 8.29$, $cv=3.46$, $p < 0.05$). T-test was performed in order to find out the most and least efficient conditions in terms of errors. The results are shown in Table VI. The results demonstrated that the textual condition was significantly the least efficient condition in terms of errors rate. Also, graphical condition was found significantly more efficient than the textual condition. However, the multimodal condition was significantly more efficient than the graphical and textual conditions. Therefore, it was the most efficient condition in terms of errors carried out.

VIII. DISCUSSION

The experimental results demonstrated that presenting email threads in the main view with unrelated messages will most likely lead to serious usability problems. Users had difficulties deciding whether messages are related to threads or not since they were overwhelmed by the large volume of presented messages in the inbox. Consequently, experimental tasks were completed in the textual threads approach with dramatically increased time when compared to the approaches used the temporal view (i.e. graphical and multimodal approaches) for displaying threads. Hence, tasks completion rate was also decreased in this approach. The identification of messages information (e.g. priority and attachments) was also affected by the clutter of the inbox although they were communicated in the common way used in most email clients (i.e. graphical icons) as well as various type of errors were observed frequently occurred. In the contrary, the results also showed that the readability of email threads can be improved by presenting them individually in a temporal view. This approach helped to reduce the complexity of the email inbox, too. Therefore, the usability drawbacks mentioned previously were significantly overcome in the approaches used this method of presenting threads (i.e. graphical and multimodal). For example, users could easily identify the characteristics of threads such as number of messages, unread messages and chronology. Hence, time taken to complete experimental tasks and errors carried out whilst performing these tasks were significantly reduced when compared to the textual threads approach.

The experimental results showed that the auditory metaphors used in the multimodal approach could not improve users' performance in terms of time in all experimental tasks in comparison with the graphical approach. This is mainly because of users were imposed to put the mouse cursor over each message icon in the thread to find out its properties. However, other usability aspects were considerably improved using these metaphors such as errors rate and threads readability. For instance, rising pitch metaphors helped users identifying number of unread messages at a glance from the main view. Identifying such information in the textual approach was found a difficult task particularly with threads contained large number of messages. As a result, time taken to complete the tasks in which users needed this information (i.e. T3, T4) to find threads was dramatically reduced when compared to the textual approach as well as errors rate. Hence, tasks completion rate was also improved in this type of tasks. Graphical representation used in the graphical approach to communicate this type of information was also found more effective than the textual approach in some usability aspects. Though, experimental results demonstrated that rising pitch notes were more usable in communicating number of unread messages in threads than the graphical representation.

Priority of email messages in threads were more identified in the textual approach when compared to the graphical and multimodal approaches. Moreover, the auditory icon used to communicate the existence of attachments in email messages were found very similar in terms of identification to the conventional icon used in the textual condition. This is mainly due to the familiarity of users with the icons used to communicate such information. Nevertheless, experimental results indicated that tasks accomplishment time, errors rate and tasks completion rate were improved in the multimodal approach when compared to the textual approach in spite of the high level of identification. Furthermore, the results showed that earcons used to communicate the priority of email messages and the auditory icon used to communicate attachments were more recognised than colours. This difference became more explicit with complex email threads (i.e. last three experimental tasks). For instance, errors rate, correct answers and tasks completion rate in the graphical approach reached to a level near or less to the textual condition in the last three experimental tasks although some of these variables were enhanced in the graphical approach in the rest of the tasks. Furthermore, these tasks were also completed in the multimodal threads with an overall improved usability when compared to the graphical approach. The main reason behind these results is that communicating such information aurally helped completing these tasks with a reduced visual overload.

The graphical representations used to communicate chronology of email messages and people contribution within threads helped users identifying such information easier in the graphical and multimodal approaches when compared to the textual approach. Furthermore, task 5, in which this type of

information was needed to find a thread, was completed with extremely enhanced usability (i.e. tasks accomplishment time, errors rate and tasks completion rate) in the graphical and multimodal approaches in comparison with the textual approach. However, conveying various data of email messages aurally in the multimodal approach helped to expand the area used to communicate this information graphically. The experimental results demonstrated that this expansion helped users identifying number of messages sent on the same day and people participated in threads easier than the graphical approach (Questions 5 and 6).

Experimental tasks were completed in the graphical and multimodal approaches with significantly reduced time when independently compared to the textual approach. Experimental results also showed that the overall mean value of time taken to complete all experimental tasks in the multimodal approach was reduced when compared to the graphical approach. However, this difference was not found statistically significant. This is mainly because of two reasons. First, the similarity of presenting threads in both approaches. Second, users were impelled to put the mouse over each message in the multimodal approach to find out its properties. Also, the experimental tasks were accomplished in the graphical and multimodal approaches with significantly reduced errors when independently compared to the textual approach. However, experimental results also showed that errors carried out whilst performing the tasks in the multimodal approach was remarkably reduced when compared to the graphical approach. This difference was statistically significant. Hence, multimodal approach was the most efficient approach in terms of errors rate where the least efficient one was the textual approach. Thus, graphical and multimodal approaches were found more efficient than the textual approach. Therefore, the hypotheses regarding the efficiency of graphical and multimodal conditions were confirmed.

Statistical results indicated that multimodal approach was significantly more effective in terms of tasks completion rate and identification of threads information when compared to the textual approach. Therefore, the two hypotheses regarding the effectiveness of multimodal condition towards the textual condition were confirmed. Moreover, tasks completion rate was higher in the graphical approach than the textual approach. However, this difference was not statistically significant. The identification of threads information was also degraded in the graphical approach when compared to the textual approach. Therefore, the hypotheses regarding the effectiveness of graphical condition towards the textual condition were rejected. Furthermore, number of users who completed all tasks in the multimodal approach was higher than the graphical approach. However, this difference was not significant because this variable was measured based mainly on time where most experimental tasks completed in both conditions with similar time. Statistical results also showed that the identification of threads information was significantly improved in the multimodal approach when compared to the

textual approach.

In conclusion, multimodal threads approach was found more effective and efficient in terms of all usability metrics than the textual approach. On the other hand, graphical threads approach has failed to become more effective than the textual approach although it was more efficient. The results of the empirical study demonstrated that the multimodal approach was more usable than the graphical approach in terms of all usability metrics except those depended on time (i.e. tasks completion rate and tasks accomplishment time).

IX. CONCLUSION

This paper described the design of three email threads approaches: textual, graphical and multimodal. In the textual approach, related messages were displayed in the main view with chronological and contextual information. In the graphical approach, messages were presented graphically in a temporal view where all types of information (chronological, relationships and contextual) were provided. The same approach was used to present threads in the multimodal approach with some information communicated aurally in order to reduce the visual overload. The results indicated that presenting email threads in the main view can significantly reduce the usability of email clients in contrast with the temporal view. The effectiveness of the graphical approach was significantly degraded when compared independently to the textual and multimodal approaches. This is because of the difficulties faced by users in recognising the graphical representations used to communicate threads information specifically with complex email threads. On the other hand, auditory metaphors (i.e. rising pitch notes, earcons and auditory icons) used to communicate the same information were found more recognised. Therefore, the multimodal approach was found more usable than the graphical approach. However, the results demonstrated that there was not a significant difference between them in terms of tasks accomplishment time because of the similarity between the two approaches and the nature of communicating information aurally.

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