Multimodal e-Government Interfaces: Increase Usability with the Aid of Expressive Avatars

Dimitrios Rigas and Badr Almutairi

Abstract—This paper examines the impact of multimodal interaction metaphors on ease of use in terms of efficiency, effectiveness, user satisfaction, user trust and communication performance of users in e-government interfaces. This study has been implemented by developing two different conditions on an experimental e-government platform. The first condition was based on the use of the avatar facial expression with text to present the messaging content between the sender and receiver. The second condition was concerned with using a combination of new multimodal metaphors (avatars with full body and text) to communicate the same information. These conditions were then empirically evaluated by two independent groups of users. Both conditions measured the performance of user on typical tasks and evaluation questions. The results obtained from this experiment confirm that multimodal metaphors do in fact help to improve usability and user perception of trust on e-government interfaces. They reduced the time needed for users to respond to messages, enabled users to undertake activities more accurately, users were more satisfied with the interface and had a positive influence on the perception of trust. Therefore, the improved parameters were effectiveness, efficiency, user satisfaction and user trust. It is therefore proposed to include multimodal metaphors in e-government interfaces, and this need to be taken in mind when designing such interfaces.

Keywords—avatars, e-government interfaces, multimodality, user trust, user interfaces.

I. Introduction

MANY e-government interfaces are crowded and not always communicate information to users correctly. These interfaces often use visual means to communicate information (often text with graphics). The user interaction could improve significantly if additional channels (e.g. auditory) to the visual one are added. This paper presents an empirical study to investigate the usability aspects of an e-government interface that incorporates a combination of traditional metaphors (e.g. text and graphics) with multimodal metaphors (expressive avatars with body gestures). Parameters investigated included users' attitudes towards expressive avatars when employed as virtual messengers as well as the user predisposition to trusting the specific interface. This investigation could help understand the role of expressive avatar within multimodal e-government user interfaces.

An e-government experimental platform, with two interface versions, was developed to serve as a basis for this investigation. The e-government software solution described uses an input interface to send messages and an output interface to receive messages. The study involved two groups of users that used the two interfaces to perform a common set of tasks. The usability of the two interfaces was measured in terms of efficiency, effectiveness, user satisfaction and user predisposition to trust.

II. Literature Review

A. Multimodal Interaction and Avatars

"*The auditory channel, as a whole, has been neglected in the development of user-interfaces, possibly because there is very little known about how humans understand and process auditory stimuli*" [1]. Multimodal metaphors offer interaction using more than one channel of communication. The additional communication metaphors increase the volume of information communicated and often better understood by users. Rigas et al, suggest that the use of multimodal metaphors in a variety of user interface circumstances [2]. Also, they found that the use of speech and non-speech in interface application helped the users to make fewer mistakes and reduced the time taken when accomplishing their tasks [3]. Other studies have been carried out to test the use of multimodal metaphors in a visual user interface and to evaluate and examine the effect of these metaphors on the usability of computer applications [4 and 5]. An avatar provides a multimodal interaction metaphor that engages the visual and auditory human senses. It is a computer-based character that has been utilized to virtually represent one party in an interactive context [16, 17] with the ability to communicate verbal and non-verbal information [18, 19]. Verbal communication refers to the use of speech and written messages, whereas nonverbal communication can be attained by facial expressions [20]. In general, avatars can be classified as abstract, realistic and naturalistic. An avatar allows the

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system to communicate information to users in a way that resembles the way that people communicate. Use of the avatar is compared with video messages or recorded messages during this study. The efficiency and effectiveness of the messages can be determined by the time and number of mouse clicks as well as user satisfaction.

B. Usability Evaluation of e-Government Interfaces

Usability is one of the most important factors to evaluate Human-Computer Interaction [6] and software quality [7]. It is defined as the "*extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction*" [8]. An effective system can be developed only by understanding the interfacing requirements, expectations of the users' under the citizen-centric approach, and the barriers that might hinder them to provide the desired services through the Internet [9]. This technology can be used to improve the efficiency of e-government interfaces, interaction between the government services and the public, facilitate economic development, reduce costs, and meet citizens' expectations for service delivery [10 and 11].

C. Trust Factor

Social sciences recognise trust as an important factor that mediates many aspects of human behavior [12, 13 and 14]. There are several definitions of trust but a widely accepted one is: "*a psychological state comprising the intention to accept vulnerability based upon positive expectations of the intentions or behavior of another*" [15]. Thus, a person (the trustor) who depends on someone else (the trustee) expects to reduce the likelihood or the size of a negative outcome in any situation. When that dependence is misplaced, the expected value of the outcome is lower. The online environment does not allow the natural benefits of face-to-face communication and to directly observe the service provider's behavior. This serves as an assurance mechanism on which humans have depended to form a trust judgment. Based on this trust paradigm, new service paradigms could emerge that could develop passive citizen participation into active citizen participation in public service delivery [22]. As the characteristics or features of online communication have the ability to decrease or increase the level of citizens' trust, it would be valuable to understand the influencing factors and their contribution. This will then help with ensuring that these factors are executed in such a manner that ensures that citizens can place the optimal level of trust in e-government.

III. AIMS AND OBJECTIVES

One of the main aims of this study was to evaluate the usability in terms of effectiveness, efficiency, user satisfaction and the perception of trust in e-government interfaces that incorporate full body expressive avatars in virtual message presentation. It is also focused on the evaluation of the effectiveness and efficiency of supporting auditory messages associated with the live message presentation of the full-body expressive avatar. Furthermore, the study measures user satisfaction and trust in relation to the e-government user interface. The objectives of this study were:

1. Development of experimental multimodal e-government platforms with typical e-government interface functionalities. This platform is referred to as the Avatar enhanced Virtual Message with Body Gestures Platform (VMBG).
2. Evaluation of the two e-government platforms by two groups of users.
3. Measure the efficiency of user performance using the time taken by users to complete the required tasks.
4. Measure the effectiveness of user performance using the frequency of tasks successfully completed by users.
5. Measure the user satisfaction and trust using post-experimental questionnaires to determine and assess the users' attitudes to the e-government platform.

IV. EXPERIMENTAL E-GOVERNMENT PLATFORM

The e-government platform was specially developed for this empirical investigation. The platform provided two different interface versions. It was specially designed to utilise speaking avatars with human-like facial expressions, and speaking avatars full body gestures. Both interface versions of the experimental platform were designed to deliver the same information about software representation of a given message. Each interface was divided into an *input* and *output section.* The software provided three message types. These were *suggestion*, *complaint* and *comment* and they included explanations about specific requests. There were three examples of common message types with three different complexities (easy, moderate, complex). The complexity of these examples was gradually increased. In addition to question type, this study also investigated the effect of two types of evaluation questions; recall and recognition for the usability of the e-government interfaces tested, as well as on users' performance in terms of the output interface's property.

A. Virtual Message with Facial Expressions Condition (VMFE)

Fig. 1 and Fig. 2 shows example screenshots of the avatar e-government interface. The interface provides command buttons to enable the message to be presented. It also provides two separate components for the message process, namely the speaking expressive avatar. The interface is divided into two parts, the first part is the input interface and second part is the output interface. These were designed to include the following components: a text box to present the user with information and a speaking expressive avatar box.

B. Virtual Message with Body Gestures Condition (VMBG)

Fig. 3 and Fig. 4 illustrate an example of this condition with full-body expressive avatars. This approach could be considered as the closest to a face-to-face communication. Three facial expressions were used in the VMFE condition and ten body gestures were used in VMBG.

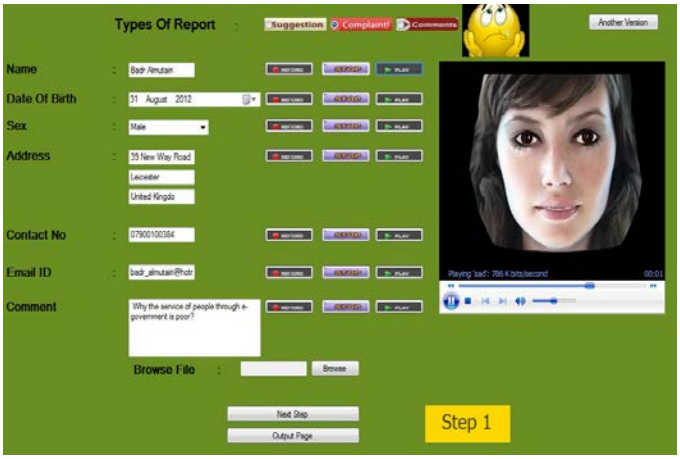

Fig. 1 The VMFE condition input interface

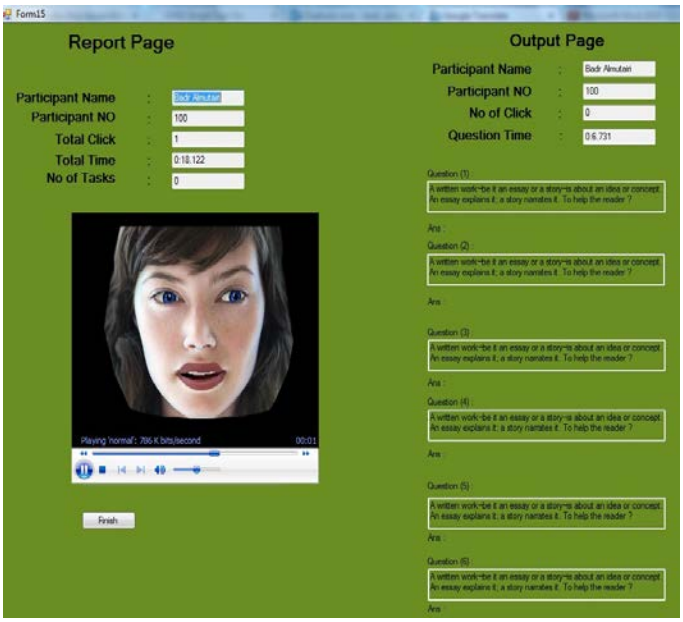

Fig. 2 The VMFE condition output interface

C. *Experimental Design*

Two groups of users were associated with the evaluation of the VMFE and VMBG conditions. The sample was 30 users in total and participated in the experiment on an individual basis. This experiment data was collected in three stages. The first part was the pre-experimental questions for the profiling of users. The second part investigated the users' evaluation (positive or negative or neutral) when using facial expressions or full body gestures in the experiment. Each expression and gesture was shown to users as still images on the screen. In the third part of the experiment, the experimental conditions were demonstrated to users and the experiment progressed with the tasks. The aim was to obtain an overall viewpoint of the users' perceptions of the same expressions and gestures but in the presence of an interactive context.

Fig. 3 The VMBG condition input interface for e-government

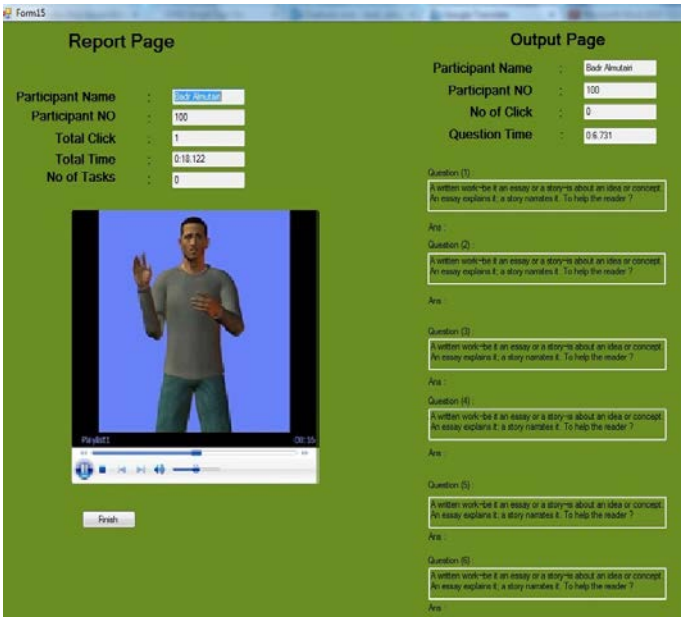

Fig. 4 The VMBG condition output interface for e-government

V. DATA COLLECTION

The data collection process was based on experimental observations and questionnaires. For each task, each user was required to complete nine tasks and to answer six questions. The time spent to complete the message tasks and to answer each of the six questions was recorded to help measure the efficiency. However, in order to collect the data related to effectiveness, the correctness of users' answers was checked and the total number of successful users, who completed the message tasks and answered questions, was counted for each user. The pre-experimental part of the questionnaire gathered personal data about users such as age, gender and education. It also helped to obtain data related to users' prior experience with computers, Internet and e-government. Finally, the post-experimental part of the questionnaire gathered the users' satisfaction with the e-government platform tested. Users' responses to this questionnaire were used to calculate the satisfaction score for each user in both the control and the experimental groups.

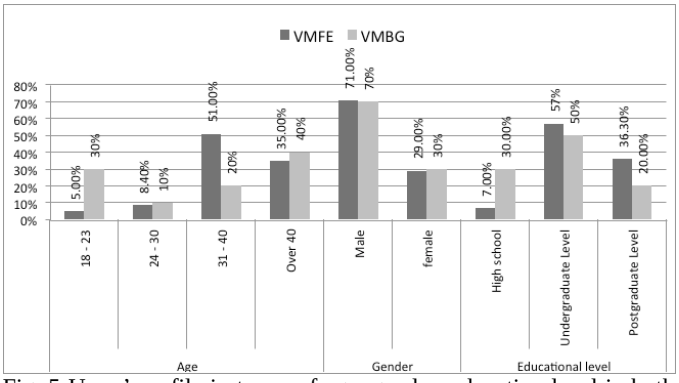

Fig. 5 Users' profile in terms of age, gender, education level in both control and experimental groups

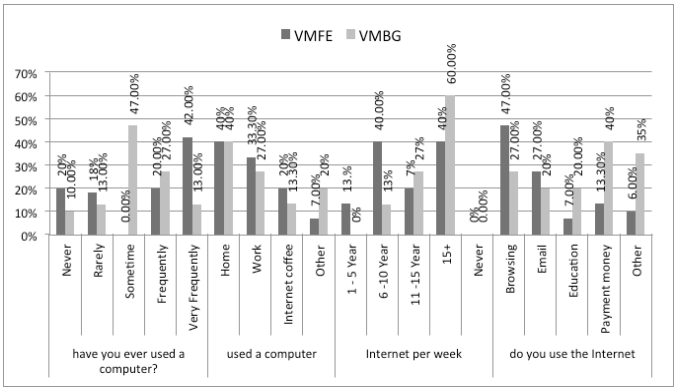

Fig. 6 Prior experience of users in both the control and experimental groups

The users' personal and educational information, as well as their previous computing knowledge and experience was collected and analyzed on the basis of their responses to the pre-experimental questions (refer to Appendix). Figure 5 shows that the age range in the control group was 51 % within 31 – 40, 35% over 40, 8.4% 24 – 30 and 5% 18 – 23 years old. In the experimental group, 40% were over 40, 20% 31 – 40 and 10% 24 – 30 and 30% 18 – 23 years old. The majority of the participants were male (71% in the control group and 70% in the experimental group). The education level was found to be predominantly postgraduates by 36.3% in control group and 20% in the experimental but undergraduates represented 57% in control group and 50% in the experimental. In addition, 7% were from high school in the control group and 30% in the experimental. Figure 6, show that most participants are expert users of computers in the control group, 42% very frequently and 13% frequently in the experimental group. Forty percent of the control group use computers from home and 40% in the experimental group. 33.3% of the control group use computers from work and 27% in the experimental. The weekly use of the Internet in the control group is less than fifteen hours a week, compared to hours in both the experimental group and control group. Over 47% use the Internet for browsing in the control group and 7% in the experimental. In addition, less than 7% of the sample users were using the Internet for education. 20% in the experimental group and 27% control groups were using it for email. Finally, Figure 6 demonstrates that both groups, to a large extent, were equivalent in terms of users' individual characteristics and prior experience.

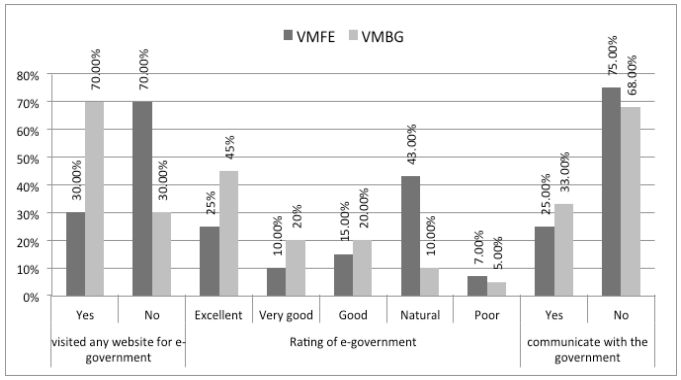

Fig. 7: Learn how to use e-government for users in both control and experimental groups

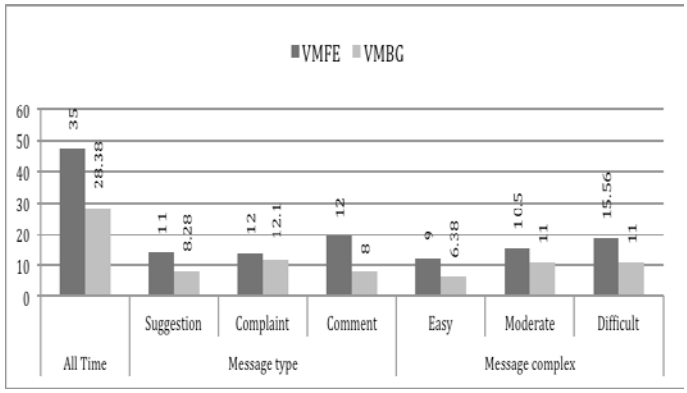

Fig. 8 Mean values of time taken by users in both groups to enter all tasks (Input interface)

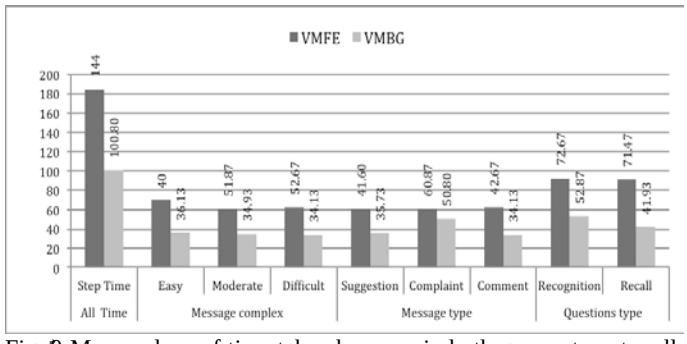

Fig. 9 Mean values of time taken by users in both groups to enter all tasks (Output interface)

Figure 7 shows that the experimental group was more experienced in e-government applications in comparison with the control group. Therefore, any differences between the two experimentally obtained results could be attributed to the treatment of the participants.

VI. EFFICIENCY RESULTS

The time taken to perform tasks and answer the required questions was used as a measure of efficiency. This measure was considered for all tasks for the input and output interfaces according to the question type (recall or recognition) and complexity of the message. The control group spent a total of 35 minutes and the experimental group 28.3 minutes. Figure 8 shows the mean values of the time taken by all users. The

experimental group (Figure 9) took less time to complete the tasks. The use of avatars appeared to improve efficiency, as

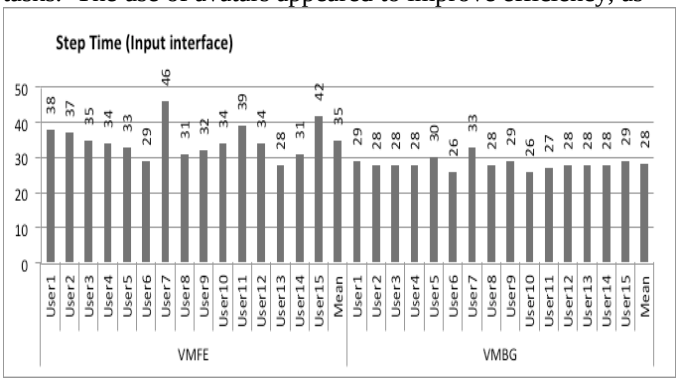

Fig. 10 Mean values of time taken by the users in both groups to enter messages for each of the tasks in the input interface

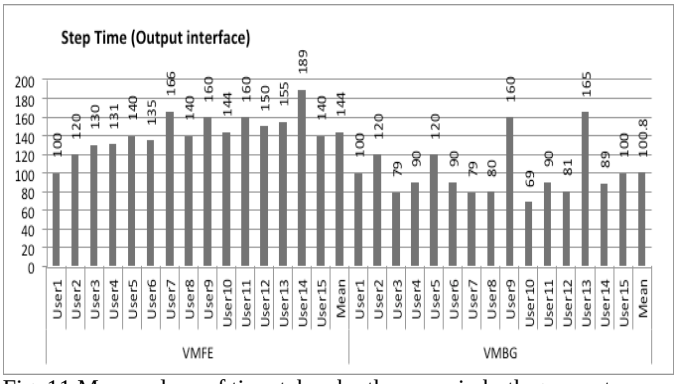

Fig. 11 Mean values of time taken by the users in both groups to enter messages for each task in the output interface

tasks took less time - unlike the other group that their users took more time to complete the tasks in the output interface. Figure 10 show the time taken to enter message tasks for each group. Apart from the 9th tasks, which needed a long time to complete by the VMFE group, the experimental group needed shorter times than the control group to enter messages for all the tasks. Moreover, the mean time taken to enter a message task was 28.38 minutes for the experimental group, compared to 35 minutes for the control group. It was noticed that the difference between the two groups for message times varied across the nine tasks for the input interface. These variances could be attributed to the differences in complexity and the type of task or because of the new effects, which were added, attracted the attention of users.

Major differences were obtained for the experimental group. Still so, the results obtained could not be considered as conclusive for clarifying the role that the full body avatar played in shortening the message time when used in the input interface. The control and experimental groups are equal in terms of the complexity of the required tasks - the control group enter text and avatar facial expression and the experimental group enter text and avatar full body gesture in the input interface. These tasks were designed to explore the individual role of these multimodal metaphors. In a few words, the multimodal metaphors used in the VMFE and VMBG assist in reducing the message time for most users undertaking the required tasks for the input interface. Figure 11 shows the total time spent by each user in both groups to enter messages for all the six tasks. VMFE users spent less time than VMBG. The minimum and maximum message

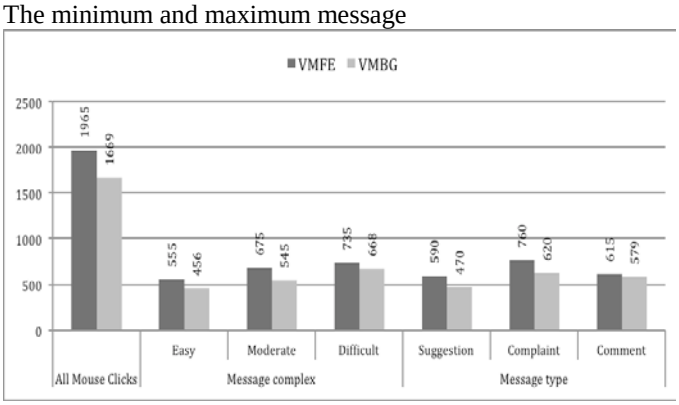

Fig. 12 The mean number of mouse clicks performed by users in both groups to enter messages for all the tasks (Input interface)

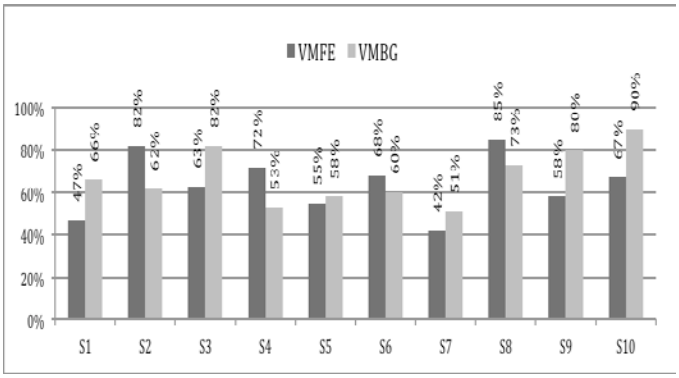

Fig. 13 Percentage of users agreeing to each statement of satisfaction, for both the VMFE and VMBG groups

Times taken by the control group were 100 seconds (User 1) and 189 seconds (User 14), correspondingly. In the experimental group, the minimum time taken was slightly lower (69 seconds by User 10), whereas the maximum time (165 seconds by User 13) was less than that in the control group. On average, the users of the VMBG were 100.80 seconds faster than their counterparts who used the VMFE.

VII. EFFECTIVENESS RESULTS

The frequencies of correctly completed tasks were used as a measure of effectiveness. This measure was considered for all tasks and questions, according to the question type (recall and recognition), message complexity (easy, moderate and difficult) and message type (suggestion, complain and comment), as well as for each user in both control and experimental groups. This measure was considered for all the tasks for each group per user. Figure 12 shows the percentage of mouse clicks to enter messages for all tasks for the VMFE and VMBG interface versions of the e-government platform. Users of the VMBG used less mouse clicks that users of the VMFE. The reason for this is the enhanced input interface used by users when using the new avatar tool as full body and improved the performance of communications. Users of the VMFE were 78% correct and VMBG users were 99% correct in the input interface. Users of the VMBG complete more tasks successfully than VMFE users, in terms of the number of

correctly entered messages for tasks using the output interface. The VMBG was more effective in communicating messages and considerably assisted the users in the experimental group to achieve a higher effectiveness rate.

VIII. USER SATISFACTION

Users' responses were gathered using a questionnaire with 10 statements. They were designed to measure the post-experimental user attitude and predisposition to developing trust towards the interface they used. The overall satisfaction score for each user was calculated using the SUS (System Usability Scale) method [21]. Figure 13 shows the mean values of user satisfaction scores.

4.17 Perception of Trust

If party A trusts party B for a service X, trust is the measurable belief of A in that B will behave dependably for a specified period within a specified context (with regard to service X) [52]. Therefore a number of features of online communication have the ability to both decrease or increase the level of citizens trust, it would be valuable to understand which factors and what levels will have desirable effect and which would not. This will then help with ensuring that these factors are executed in such a manner that ensures that citizens can place the optimal degree of trust in e-government.

Participants generally responded favorably to VMBG when questioned on the five trust aspects as outlined in the previous experiment and this shows when using multimodal approach and then increase trustworthy. From table 13, it is identifiable that 60% of VMFE users were in agreement that the system's features offered matched with what their expectations, in comparison to 80% of VMBG users. It was also noted that 87% of VMBG users possessed a belief that the system portrayed an honest impression overall, in comparison to 67% of the users of VMFE. Furthermore, 87% of VMBG users intended place a greater reliance on their prior experience than the actual content provided by the system compared to 73% of the users of VMFE. In addition to this, 53% of the users of VMFE felt this interface was incompetent and unprofessional, in comparison with 47% of the users of VMBG who were in agreement with this statement. Only 20% of VMFE users felt the system to be trustworthy, whereas approximately 87% of VMBG users believed in the trustworthiness of the condition. In summary, the responses of users identified multimodal approach effects were demonstrated in all aspects of user trust. In addition, results obtained from the chi-square test suggested that the difference between TOEGP and VMBG was insufficient with regard to Statements S1 ($X^2 = 20$, df= 1, $p< 0.05$) and S2 ($X^2 = 12$, df= 1, $p< 0.05$) and S3 ($X^2 = 9$, df= 1, $p< 0.05$) and S4 ($X^2 = 50$, df= 1, $p < 0.05$) and S5 ($X^2 = 11$, df= 1, $p< 0.05$) and use chi-square test because all the data were of the type categorical data. In brief, multimodal interaction has a considerable effect on aspects of Perception of Trust.

IX. DISCUSSION

The results obtained provide a comparison point between the interfaces The study also focused on the factors that can affect the role of multimodal interaction metaphors, such as the message type (suggestion, complaint, comment) the message complexity level (easy, moderate and difficult) and the question types (recall and recognition). The results obtained showed that the full-body expressive avatar significantly improve the efficiency of tasks and users.

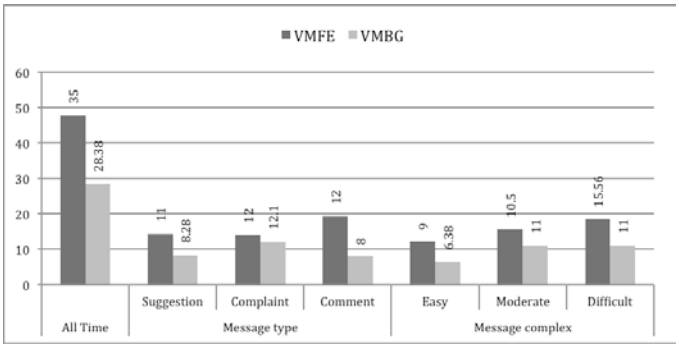

Fig. 14 Mean values of time taken by users in both groups to enter all the tasks, grouped by message complexity and message type (Input interface)

There were more effective in the input interface. In addition, the same multimodal metaphor improved users' efficiency and effectiveness when used in the output interface, compared to the avatar facial expression approach for communicating the message content.

Figure 14 demonstrates that using the multimodal interaction metaphors increased the time needed by users in the control group to enter messages in the input interface. However, there was a significant reduction in the time needed by users in the experimental group to respond to the evaluation questions in the output interface. The reason was that the full body avatar enhanced the interaction process for each task when users sent messages. Therefore, the tasks took less time to be completed during the use of the input interface. Experimental observations highlighted that users in the experimental group took less time because they were concentrating on the full body avatar. Therefore, users in the experimental group were significantly aided by the addition of these metaphors in the VMBG, in terms of spending less time to answer questions. These results suggest that the use of the full body avatar can significantly improve efficiency than the use of the avatar facial expression metaphors when presenting information.

The VMBG platform was more efficient for both recall and recognition questions than the output interface. On the whole, the experimental findings indicated that the addition of the full body avatar contributed to the memory recall of users. Figure 16 shows the time taken by users to answer recall and recognition questions. The experimental group had generally lower time for both types of questions. The recall questions taken shorter time to the recognition ones.

The VMBG group outperformed users of VMFE in the number of mouse clicks that measured performance of communication and tasks complete successfully. Figure 12 shows that the VMBG condition was better than the VMFE for reducing the number of mouse clicks. This was due to the use of the full body avatar in the input interface for the

experimental group, in comparison to the sole use of avatar facial expressions to convey messages to the control group. These metaphors enabled the retention of information for a longer. As the experimental group users were able to remember the communicated information for a longer period of time (in comparison with the control group), they were able to attain a considerably greater number of mouse clicks than their control group counterparts. In addition, the multimodal interaction metaphors used in the VMBG were more effective and considerably assisted the users in the experimental group to achieve a higher effectiveness rate.

The VMBG group accomplished a substantially larger number of correct answers than their counterparts in the VMFE for both recall and recognition. In order to successfully answer the recall questions, users had to correctly retrieve from their memory part of the communicated messaging content. The results of this experiment indicated that new multimodal metaphors enabled users to understand the questions better, without distracting their attention away from the presented content. The rates of recognition questions were 55% for the VMFE compared to 100% for the VMBG. This demonstrates that users' memory was not aided when they used the interface with the recorded speech.

The multimodal presentation of the message content in the VMBG was shown to be significantly more satisfying than the avatar facial expression interface in the VMFE. The use of full body avatar was more effective for users in the experimental group. Users expressed a positive attitude towards the audio-visual communication of messages. The multimodal aided e-government interface is more likely to result in an agreeable and satisfying experience for the user.

A. Empirically Derived Guidelines

The results of these experiments as well as the results of previous experiments [22-25] enabled the development of a set of empirically derived guidelines for the design of more usable e-government interfaces.

Recoded Speech. It was shown to be a fundamental component in interactive multimodal e-government interfaces. The obtained results demonstrated a significant contribution of recorded speech in delivering a clear and understandable spoken message to users. Users expressed positive views towards the tested e-government interfaces. For example, different tones could be used to stress users‘ attention to specific key words or statements in the delivered message content. The use of recorded speech prevents users from switching their attention away from the graphical representations or visual area of focus. The use of speech output will often reduce the working memory load of users.

Facially-expressive avatars. They were found to be the most liked and best rated by the users. The implementation of these expressions in an avatar during the communication of a message, makes the presentation better understood by users. These expressions could be used to change the tone of the presentation and attract users to think of the presented information.

Expressive avatars with body gestures. Some body gestures in full body avatars help to effectively communicate a message. These gestures are neutral, hands down, hands behind, open hands, walking, contemplate, paws opposite, chin stroking, opposite legs and indicate. Users also, preferred these gestures.

Integrating the metaphors. Combining a full body avatar and placing the textual content in the background, during the communication of a message, maximises the benefit of body gestures (e.g. walking and pointing). This is particularly useful when users are guided to specific displayed messages in the interface. The use of a face-only avatar may result in overloading users as they may be searching for the information related to the spoken message.

Non-speech Auditory Stimuli. Earcons and auditory icons are effective in annotating the spoken message expressed by an avatar (e.g. a bell and door or bottle opening can signal the beginning of a message and a door closing can indicate the end of that communication). Earcons can be used to highlight specific key words during communication.

X. CONCLUSION

This paper examines the impact of multimodal avatar-based interaction in e-government interfaces for ease of use, in terms of efficiency, effectiveness and user satisfaction and trust. This study has been implemented by developing two different experimental e-government platforms. The first platform was based on the use of facially expressive avatars and the second platform full body gestures and facial expressions avatars. These two e-government interface platforms were empirically evaluated by two independent groups of users. These groups of users evaluated their corresponding interface by performing experimental tasks and answer evaluation questions.

The results obtained from this experiment confirm that expressive avatars improved usability, development of user trust, reduced response time to messages and allowed users to complete tasks more accurately. They also made the use of the interface more pleasing and satisfying to users. This has also been observed in other work [26, 27, 28 and 29]. Therefore, the use of these particular metaphors improved the performance of users and ease of use of e-government interfaces in terms of effectiveness, efficiency and user satisfaction and trust. The same effect was also observed in other domains [29, 30 and 31]. It is therefore proposed to include expressive avatars in e-government interfaces, and this need to be considered when designing such interfaces.

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