A usability evaluation of multimodal metaphors for customer knowledge management

Mutlaq B. Alotaibi and Dimitrios I. Rigas

***Abstract*—** Many factors explain why customers are reluctant to exchange knowledge, but this paper places emphasis on the influence of designing interactive interfaces. The paper describes an empirical investigation carried out to evaluate the usability of incorporating multimodal interaction metaphors into Electronic Customer Knowledge Management Systems (E-CKMS) interfaces. To address this aim, a comparative evaluation was conducted on three E-CKMS interaction modes designed for this study. The control condition was text with graphics E-CKMS (VCKMS), and the experimental conditions were both multimodal. The multimodal platforms used a combination of speech, earcons, and auditory icons (MCKMS), and another combination of speech, earcons, and avatars with facial expressions (ACKMS). Three independent groups of users (n=20 for each group) evaluated the three platforms by performing eight common tasks of three different types and increasing complexity. Results suggested that the experimental conditions were more usable than the control in terms of efficiency and user satisfaction.

***Keywords*—** Expressive Avatars, Facial Expressions, Usability Evaluation, Customer Knowledge Management

I. Introduction

THE innovative manners of conducting business with the aid of Information Technology (IT) led to a dramatic shift from information to knowledge societies [1]. Therefore, harnessing intangible assets is becoming one of the primary sources of creating and sustaining competitive advantage in the age of knowledge [1]. The concept of Knowledge covers a vast area of various views, principles, and taxonomies [2]. One of the proposed knowledge taxonomies is based on knowledge elicitation sources, which organises knowledge into external and internal [3]. External knowledge refers to the assets reside in the heads of customers, i.e. Customer knowledge (CK). CK has shown to be one of the most organisations valuable types of knowledge [4], because is gathered at the customer point of contact, and under a great deal of time pressure [5]. The organisational growth, innovation and competition against competitors are particularly linked to the manner in which CK is created, stored, disseminated, and utilised [6]-[7]. With this huge contribution, CK is still hard to gather, identify, interpret, and integrate, due to the multiple customer communication channels [8]. This led to the synergy between Knowledge Management (KM) and Customer Relationship Management (CRM) in E-Business. Further background information is provided on KM [9], CRM [10], and E-Business [11]-[12].

Electronic Customer Knowledge Management Systems (E-CKMS) is derived from the integration between KM and CRM in E-Business contexts [10]. The typical example of E-CKMS is argued to be Amazon.com [13], which illustrates how Communities of Customers (COC) work. There are several similarities between COC and Communities of Practice (CoP), which leads the argument that the COC notation is deeply rooted in the traditional KM [14]. The COC provides a platform for knowledge sharing, in which customers can share opinions and insights about products. This platform aids the process of community member decision making, by offering CRM and KM capabilities [15]. From CRM perspective, the analysis of customer behaviours and manners of navigation facilitates further understanding of customer buying patterns, and hence leveraging selling opportunities, such as up-selling and cross-selling [16]. In few words, Amazon.com case study describes KM and CRM aspects, and provides a benchmark for efforts devoted to evaluating E-CKMS.

Interactive systems is argued to be among several CRM components that facilitates effective Customer Knowledge Management (CKM) [17]. In fact, the multimodal interaction approach aims to replace the traditional CK elicitation and representation method that relies on results market research or understanding of customer representatives. The present paper describes an empirical study conducted to examine the impact using multimodal metaphors on efficiency and satisfaction. To address these aims, an experimental E-CKMS platform was implemented with three interfaces: avatar-enhance multimodal interface (ACKMS), multimodal interface with speech, earcons, and auditory icons (MCKMS), and text with graphics visual-only interface (VCKMS). This paper contributes to the literature to CKM, especially to the way by which knowledge is conveyed to customers, and introduces CKM as a new application area of multimodal metaphors [18]-[19].

The remainder of this paper is organised in five sections. In Section 2, we introduced relevant work. Section 3 described the experimental platform. Design of the empirical study is shown in Section 4. In Section 5, we presented results and discussion. Conclusion is provided in Section 6. Finally, we described future work in Section 7.

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M. B. Alotaibi is a research student at University of Bradford, Bradford, BD7 1DP, UK (phone: +44(0)1274-236830; fax: +44(0)1274-233920; e-mail: M.B.G.Alotaibi@Bradford.ac.uk).

D. I. Rigas, is a senior lecturer with University of Bradford, Bradford, BD7 1DP, UK (phone: +44(0)1274-235131; fax: +44(0)1274-233920; e-mail: D.Rigas@Bradford.ac.uk).

II. Relevant Work

Prior studies highlighted several challenges to E-CKMS that can be addressed by using multimodal interaction metaphors. For instance, the issue of knowledge hoarding [3], [5], which can be defined as customers unwillingness to share knowledge, can be tackled by various approaches, including optimising customer-company dialogue or Interaction [14], [15], [17]. Gibbert et al. [15] stated that trust and knowledge hoarding could be addressed by not only establishing continuous two-way dialog with customers, but also employing interactive multimedia systems. Another challenge is that customers ideas, during the course of interaction with E-CKMS, need to be well-structured and organised, and innovation toolkits has shown to be helpful to aid this process [20], [21]. The toolkits can be incorporated into E-CKMS in order to facilitate an optimal transformation of customer expertise and expectations into valuable suggestions, which can be afterward used to offer customised and personalised products and services. This context involves knowledge sharing, and hence motivating customer to participate in knowledge exchange is needed, which leads to the assumption that there is a potential role for multimodal interaction. Another challenge is related to aspects of information overload and relevancy, which is, actually, derived the web-based environment. Authors [3], [8] in the E-CKMS field raised information overload and relevancy as a concern, and included it with content issues, and other authors mentioned identification of relevant knowledge [22]. In the multimodal interaction field, Brewster [23] argued that this could be addressed by enhancing the visual-only manner of information display with metaphors of audio-visual nature. In summary, the use of multimodal interaction is anticipated to address trust, structure and content questions in E-CKMS.

A. *Trust*

Trust is an important aspect of online business, due to the lack of face-to-face interaction, and formal assurance (e.g. printed receipts) typically found in the traditional retailing [24]. The concept of trust covers a cognitive assessment of the goodwill and credibility of the partner (trusting beliefs), as well as behavioural intentions that reflects the willingness to rely upon the partner [25]. It has been argued that behavioural trust is influenced by cognitive trust, and measuring both components is regarded as redundancy [25]. This argument is based on the theory of reasoned action (TRA) that stated that behavioural intentions are influenced by attitudes, which are built around beliefs [26]. Beliefs are categorised, in cognitive trust, based on the level of perceptions of individuals into ability (beliefs of the partner skills), benevolence (beliefs of the partner personal interest), integrity (match between perceived and expectation value [27]), and honesty (beliefs of the partner desire to keep promises) [24]. In the context of CKM, lack of customer trust was raised as an issue in customer loyalty [25], [27] (CRM aspect), knowledge sharing [28] (KM function), E-CKMS [15], and even in face-to-face CKM [29]. In brief, the lack of trust is a common issue usually encountered by CKM initiatives.

B. *Multimodal interaction*

Few studies have evaluated the potential of multimodal metaphors to improve E-CKMS usability. However, several experiments have been conducted to evaluate such role in different fields, and found that user interface can be enhanced by incorporating speech [30] and non-speech sounds (earcons [31]-[32] and auditory icons [33]). In the software engineering field, several studies supported this view, such as Sonnenwald et al. [34], Cohen and Ludwig [35], DiGiano et al. [36] and Rigas et al. [37]-[38]. Overall, usability can be improved in general Information Systems (IS) by employing multimodal interaction. In fact, Burke et al. [39] carried out meta-analysis investigation into the effectiveness of multimodal interaction, in forty three studies, and found that audio-visual metaphors have a significant positive influence on user performance and IS usability as opposed to the visual-only display. In addition, this observation was supported by the results obtained from two experiments carried out by Rigas et al. [40]-[41] on the use of multimodal metaphors to communicate information of Electronic mail (E-Mail) and stock control applications. Additionally, two studies [31], [42] on utilising rising pitch metaphors to communicate graphical information found that it was possible for visually-impaired users to interpret graphical information with the aid of rising pitch metaphors, even in the absence of a visual display. In brief, the use of multimodal metaphors has shown to be useful in different disciplines.

Since E-CKMS is a web-based system, it can be linked to similar fields of study [43], such as web-based browsing, E-Mail applications, and Electronic learning (E-Learning). In web-based browsing systems, a prototype has been designed as an online help system supported with sound [30], and then extended by including no-speech sound and other auditory metaphors [44]. Additionally, another web-based browsing prototype was built to browse musical notes with the help of sound, and found to be useful to improve performance [45]. In E-Mail applications, two experiments [46]-[47] were carried out to evaluate the potential of audio-visual metaphors to reduce visual complexity and tackle information hiding, and concluded that this hypothesis was true, besides that visual display have to be synchronised with auditory stimuli (speech, and non-speech sounds). In E-Learning, several experiments assessed the use of multimodal metaphors to aid the learning process [48]-[49]. For example, a study [50] on the measure of student capabilities, perception, and performance aimed to evaluate the effect of multimodal interaction on the learning process showed that multimodal E-Learning outperform the paper-based approach. This observation was supported by several experiments [51]-[52] . Another study [53] on the role of electronic multimodal interfaces on E-Learning indicated that incorporating means of synthesised speech and speech recognition contributes considerably towards the efficiency of E-learning systems, and the student learning outcomes and satisfaction. In brief, the utilisation of multimodal metaphors relates positively towards the usability of web-browsing E-Mail, and E-learning systems.

TABLE 1 DIFFERENCES BETWEEN THE VCKMS, MCKMS, AND ACKMS EXPERIMENTAL SYSTEMS

Condition	Information / Metaphors	Communities of Customers (COC)				Co-production		Product Information	
		Trends	Reviews	Ratings	Website advices	Cost	Comparison	Price	Features
VCKMS	Text		√			√	√	√	√
	Graphics	√		√	√				√
MCKMS	Text		√				√	√	√
	Graphics	√		√	√	√			√
	Speech		√				√		√
	Earcons	√		√	√		√		
	Auditory icons		√		√		√		√
ACKMS	Text							√	√
	Graphics	√		√	√				√
	Visual special effect		√			√			√
	Speech		√				√		√
	Earcons	√		√	√				
	Facial expressions		√				√		√

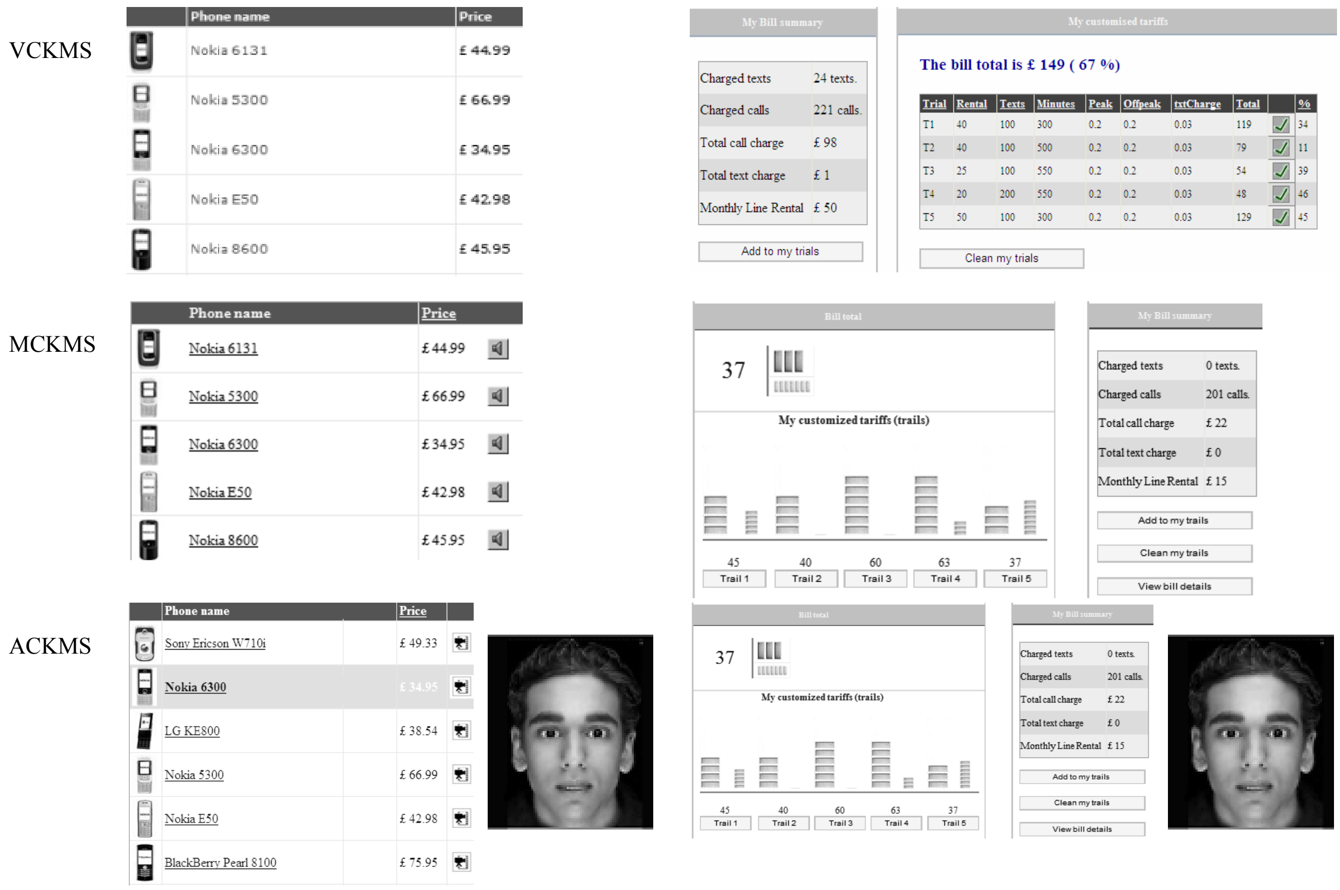
Happy Amazed Surprised Sad Tired Disgusted Neutral Thinking
Positive Expressions (a) Negative Expressions (a) Neutral Expressions (c)

FIG.1 POSITIVE (A), NEGATIVE (B), AND NEUTRAL (C) FACIAL EXPRESSIONS USED IN THE ACKMS EXPERIMENTAL SYSTEM

III. EXPERIMENTAL PLATFORM

The experimental platform developed for this study provided typical functions of web-based mobile phones retailing systems, and included an additional function labelled as co-production. Co-production was defined by Gibbert et al. [15] as the manner in which customers practice in the New Product Development (NPD) process. In this study, co-production function facilitates the dual role of customers (producer and consumer) by aiding customers to manipulate elements in solution space to test new products (billing scheme). Actually, solution space included several elements, but the scope of this study limited these elements to loyalty, billing and taffies schemes. In addition, co-production function offered a trail-and-error engine that enabled experimental NPD, and allowed its repetition until final product design was reached. This engine received customised schemes, sent it to billing engine, received customised bill, stored it in trails comparison array, and then provided comparison of results obtained from other trails in order to support customer decision making.

The E-CKMS experimental platform was implemented with three different interfaces: visual-only (VCKMS), multimodal (MCKMS) and Avatar-enhanced multimodal (ACKMS). In VCKMS, the communication of knowledge utilised the visual channel only, whereas in MCKMS and ACKMS it utilised both visual and auditory channels. This required categorisation of CK and auditory and visual metaphors, and utilisation of a wide range of technologies. First, types of CK were organised into six categories (trends, customer reviews, customer ratings, website advices, co-production, and product features). Some of CK were communicated visually, auditory or simultaneously. Second, the visual metaphors used were text, graphics, and visual special effect, whilst the auditory metaphors were recorded and synthesised speech, earcons, auditory icons, and facial expressions. Finally, in order to facilitate multimodal interaction, expressive avatars, musical notes, and speech recording software [54] were used. Alongside with speech, popular and recognised facial expressions [55] were used to communicate different types of CK, including three positive (*happy, amazed, and positively surprised*), thee negative (*sad, tired/bored, and disgusted*), and two neutral (*neutral and thinking*) expressions. Fig. 1 illustrates the facial expressions used in the ACKMS experimental system categorised into positive (a), negative (b), and neutral (c) expressions. In addition, the empirically derived guidelines provided by Brewster [56] were followed in the creation of earcons. Families of earcons was differentiated by timber [57] (*guitar, violin, trumpet, drum, organ and piano* [58]), and a further differentiation was made by utilising rising pitch metaphors to communicate different types of CK.. For example, guitar and violin were mapped to trends lists, in order to communicate the best and worst rated products respectively, and rising pitch would convey the product position in both lists. Furthermore, the environmental sounds used were sound of *typing, cheering, clapping, laughing, gasping, foghorn, side whistle and camera shot*. Table 1 shows the association between CK categories and the way by which it was communicated in the VCKMS, MCKMS, and ACKMS experimental systems. In summary, the E-CKMS Interface was designed and implemented differently based on the three environments: VCKMS, MCKMS, and ACKMS, in which different metaphors were assigned to communicate CK.



Product Catalogue (a) Co-production Interface (b)

FIG. 2 SNAPSHOTS OF THE VCKMS, MCKMS, AND ACKMS INTERFACES ACCORDING TO PRODUCT CATALOGUE (A) AND CO-PRODUCTION INTERFACE (B)

A. Product Catalogue Implementation

The product catalogue was implemented as typical tabular one, and assumed that VCKMS presented as much information and knowledge as Amazon.com interface, such as product image, name, rating, and price. Both MCKMS and ACKMS were designed to present the same information, but with additional features that allowed the user to utilise auditory cues, and video clips respectively to assess each product directly from the catalogue. In MCKMS, product features and CK, other than those provided in the product catalogue, can be evaluated aurally by clicking a button associated with each product. This button played a sequential combination of speech, rising pitch metaphors, and environmental sound to convey knowledge and information related to the product and trends of customer opinions. Similarly, the same button was provided in ACKMS product catalogue, but it played a video clip that presents an expressive avatar as a presumed sales representative. The avatar introduced product features orally, and communicated knowledge about customer opinions emotionally, alongside with earcons playing in the background to convey knowledge about product rankings (e.g. worst or top rated, and top or least recommend). In contrast, VCKMS users were required to assess such information by navigating through to product details page and, if necessary, to customer review pages.

B. Co-production Implementation

Co-production allowed repetitive NPD until the final design was reached through a trail-and-error engine that stimulated the billing process. The customer manipulated billing scheme parameters, such as monthly rental, free minutes and free tests, and invoked a billing engine, which then provided customised bill (trial). The trial was stored in a trial comparison array to facilitate trials comparison, and hence supported customer decision making. The trial comparison feature was lacking in VCKMS, because it listed the trials in a typical tabular form. In contrast, MCKMS and ACKMS utilised a graph aided by audio-visual metaphors to present information and knowledge related to trail comparison. Similar to the product catalogue approach, the comparison information was presented by auditory stimuli, and expressive avatars in MCKMS and ACKMS respectively. In MCKMS, it was required to click the left vertical bars to facilitate trail comparison by musical notes or the right vertical bars to compare more than one trial by synthesised speech. In ACKMS, the multiple trial comparisons followed the MCKMS approach, but recorded speech was used to communicate the difference between two trials, and facial expressions to convey the difference direction. Fig. 2 shows the differences between the three conditions according to product catalogue (a), and co-production interface (b).

TABLE 2 SUMMARY OF TASK DESCRIPTIONS, STYLES, COMPLEXITY, AND COMPLEXITY INFLUENTIAL FACTORS

Complexity	Task			CKM style			Complexity Factors	
	Code	Description	Product	COC	Non-COC	Co-production	NOTR	NOAS
Simple	T1	Product selection in the presence of COC	Phone	√			6	18
	T2	Product selection in the absence of COC	Tariff		√		4	22
Moderate	T3	Product selection in the presence of COC	Phone	√			7	8
	T4	Product selection in the absence of COC	Tariff		√		5	9
	T5	Co-production with two trails	Tariff			√	3	N/A
Complex	T6	Product selection in the presence of COC	Phone	√			7	2
	T7	Product selection in the absence of COC	Tariff		√		4	2
	T8	Co-production with five trails	Tariff			√	6	N/A

IV. DESIGN OF EXPERIMENTAL STUDY

This study explored usability aspects related to the use of audio-visual metaphors in three levels of task complexity, and three CKM styles. The three complexity levels were simple, moderate, and complex, and the three CKM styles were COC, Non-COC, and co-production. Although, task complexity is subjective in nature, three aspects were devoted to distinguish task complexity levels: number of task requirements (NOTR), number of available selections (NAOS), Intensity of Customer Interaction (ICI). NOTR reflected how many task requirements required to be fulfilled in order to consider the task as successfully completed, while NAOS was to refer to the number of available products that when selected by the user, the task is regarded as accomplished. When the task was designed to be complex, NOTR was increased, while NAOS was decreased. It was categorised also based on ICI into low (T1 and T2), moderate (T3, T4 and T5) and high (T6, T7 and T8) intensity tasks that reflected the three complexity levels. Burke et al. [39] provided more information on task levels, types and workload. In summary, the present study identified three CKM styles, three complexity levels, and proposed three dimensions to distinguish task complexity levels.

The task design for CKM styles utilised the nature of task. In fact, COC tasks represented product selection in the present of CoC contexts, whereas Non-COC reflected the selection in the absence of COC contexts. Types of products were phones and tariffs. There have been eight tasks in total, divided based on CKM style into COC-based selection (T1, T3 and T6), non-COC selection (T2, T4 and T7) and co-production tasks (T5 and T8). In T3, for example, a user was provided with a scenario: say that your phone preferences are, the phone should be among the top10 or website advice lists, the phone should be a camera phone with capacity between 0.5 and 3MP, a 3G phone, and the number of positive reviews should be greater than the negative ones. It was worth noting that COC-based selection scenarios included at least one requirement from the COC context (e.g. rating, trends, and website advice), whereas non-COC selection scenarios lacked the COC context. Table 2 summarises task descriptions, CKM styles, complexity levels, and task complexity influential factors. In summary, E-CKMS interaction mode, task complexity and CKM style represented the three independent variables with three levels manipulated in this experiment.

A. *Experimental Procedure*

This experimental research evaluated the difference between groups in order to uncover the causal relationship between factors. In fact, the evaluation of the three systems relied on a selected sample to evaluate the three conditions, and measure a set of variables. Sixty subjects were selected randomly from the population, based on the non-probability strategy and convenience-sampling method [59]. Subjects were assigned randomly to three groups (n=20 each), and then offered a short training session on the corresponding E-CKMS experimental platform. The subjects were introduced to examine a platform that they had not used or experienced prior to the experiment, to control user familiarity with the system. The three groups were provided with the association between information represented and the metaphors used to communicate them. The ability of users to interpret such metaphors was tested prior to the experiment through specially design tasks, in which users provided with help needed until the full understanding of perceptual context is demonstrated. Then, subjects were asked to perform the eight tasks and fill a questionnaire devised for this study. The task order was balanced as so to eliminate any possible task learning effect.

B. *Dependent Variables*

Upon the completion of the eight tasks, a set of factors were quantified and measured (i.e. dependent variables). These variables were count of mouse clicks, and count visited pages as objective factors, and user satisfaction as a subjective dimension. The count of mouse clicks and visited pages were observed and counted during the task performance, in order to reflect aspects of user efficiency in navigation. In addition, measuring user attitude towards the system appears to be difficult. However, determination of the extent, to which the user agree/disagree with a set of statements, tend to support the pursuit of this measure [60]. Satisfaction was measured by a set of user provided answers to questionnaire questions, including ease of use (EOU), extent of confusion (EOC), extent of frustration (EOF), ease of navigation (EON), and convenience (CON). User agreement and disagreement used a six-point Likert scale [61] ranging from agree strongly (6) to disagree strongly (1). Upon the completion of user satisfaction questions, responses were summed up to generate an overall score for user satisfaction based on the System Usability Scale (SUS) technique [62].

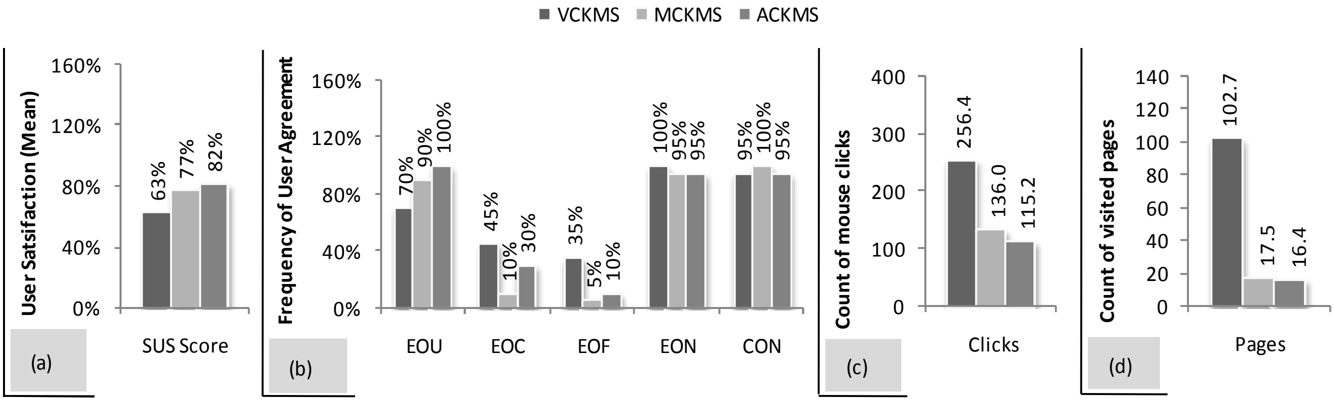


FIG. 3 MEAN VALUES OF SUS SATISFACTION SCORE (A), AND FREQUENCY OF USER AGREEMENT OF FIVE USER SATISFACTION FACTORS (B), COUNT OF MOUSE CLICKS IN HUNDREDS (C), AND COUNT OF VISITED PAGES (D) WITH THE VALUES FOR USING THE VCKMS, MCKMS, AND ACKMS EXPERIMENTAL SYSTEMS

V. DISCUSSION OF RESULTS

During the experiment, it was noteworthy that multimodal interaction improved user navigation patterns, which led to greater satisfaction. Multimodal E-CKMS interfaces have shown to be particularly more efficient than text with graphics with regard to efficiency of user navigation. Subjects in the experimental groups expressed more interest in the audio-visual knowledge communication than those in the control group. The experience gained from this study suggested that users tended to be more comfortable with aural communication when sounds conveyed more rapidly than for the first time. It was worthy noting that the extent in which auditory stimuli (speech, earcons, and auditory icons) facilitates efficient CKM involved a variation. Auditory icons, for example, showed a considerable contribution in aiding user performance, when it was used to communicate knowledge that has a well-known association with sounds in real life. On the other hand, earcons appeared to be, to some extent, less useful because it could not be interpreted as naturally as auditory icons, but it was very helpful in conveying knowledge that have relatively low range of values, such as ratings. Speech, in addition, was expected to contribute considerably to support E-CKMS user performance in tasks that involved reading very long texts, such as reviews. In addition, the use of facial expressions has shown to be particularly useful to improve navigation efficiency, and generate positive user attitudes. In summary, efficiency and satisfaction attributes provided insights into the significance of multimodal metaphors in improving E-CKMS usability.

Fig. 3 shows the mean values of SUS satisfaction score (a), and the frequency of user agreement of five user satisfaction factors (b), mean values of count of mouse clicks (c), and visited pages (d) using the VCKMS, MCKMS, and ACKMS experimental systems. In Fig. 3 (a), it can be seen that tends and levels of customer satisfaction for using the multimodal conditions were particularly greater than that for VCKMS, with regard to the average SUS score. The mean value of SUS satisfaction score for using VCKMS was just three-quarters and four-fifth that for ACKMS and MCKMS respectively. The mean value for using ACKMS was slightly lower than that for MCKMS. In Fig. 3 (b), participants' responses suggested that the multimodal platforms were easier to use, less confusing and less frustrating than the visual-only. It can be noticed that all the users agreed that ACKMS was ease to use, compared to 90% for MCKMS, and 70% for VCKMS. In EOC, it can be seen that 90% and 70% of the users disagreed that MCKMS and ACKMS was confusing respectively, whereas 45% of the users felt confused during the interaction with VCKMS. In EOF, it can be seen that 95% and 90% of the users disagreed that MCKMS and ACKMS were frustrating respectively, whereas VCKMS has frustrated 35% of the users. In addition, levels of user agreement frequency showed relatively the same picture with regard to EON, and CON, because at least 95% of the users agreed that it was easy to navigate through, and felt convenient to interact with the three systems. In summary, it can be said the use of multimodal metaphors was linked to several positive feelings that contribute considerably towards the improvement of user satisfaction. In other words, ACKMS and MCKMS were more satisfactory than VCKMS regarding all user satisfaction factors.

From efficiency perspective, user navigation patterns were considerably improved by the use of multimodal metaphors. However, the mean value of visited pages was constant for using ACKMS and MCKMS, due to the nature of multimodal interaction and user navigation patterns. In Fig. 3 (c), the mean value of count of mouse clicks, required to accomplish tasks for ACKMS, was slightly lower (15%) than that for MCKMS, but was below half that for VCKMS. In Fig. 3 (d), the average number of visited pages for using ACKMS was almost equal to that for MCKMS. However, the reduction in the average count of visited pages for ACKMS was considerable (84%), as opposed to VCKMS. Therefore, it can be said that the use of multimodal metaphors in E-CKMS interfaces has contributed considerably to improve the efficiency of user navigation. In brief, ACKMS outperformed both MCKMS and VCKMS with regard to count of mouse clicks, but the count of visited pages was kept relatively constant in ACKMS and MCKMS.

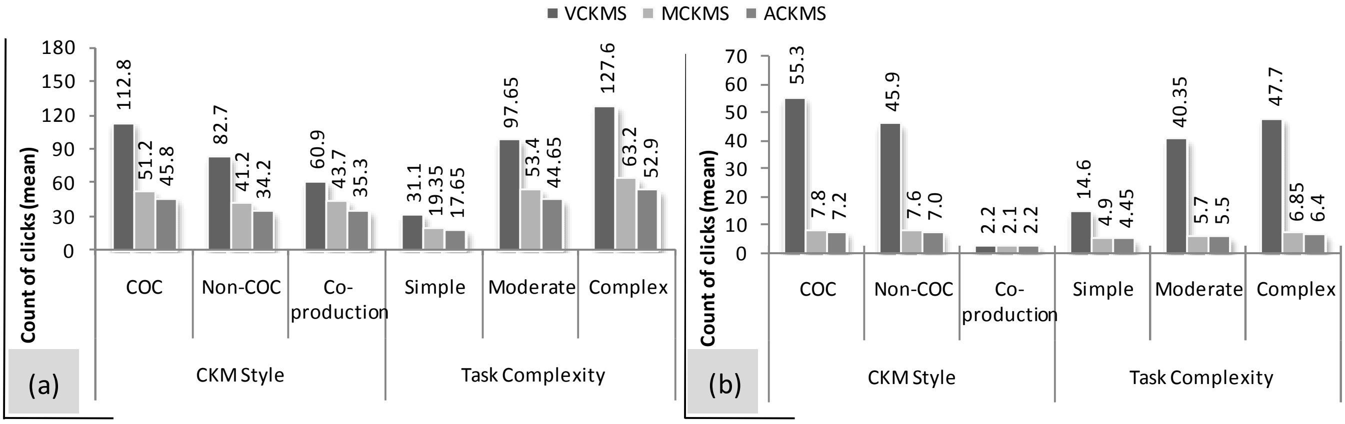


FIG. 4 MEAN VALUES OF SUS SATISFACTION SCORE (A), AND FREQUENCY OF USER AGREEMENT OF FIVE USER SATISFACTION FACTORS (B), COUNT OF MOUSE CLICKS IN HUNDREDS (C), AND COUNT OF VISITED PAGES (D) USING THE VCKMS, MCKMS, AND ACKMS EXPERIMENTAL PLATFORMS

Significance of the difference was examined by t-test [63] to perform comparisons between two interaction modes, and one-way ANOVA to compare the three interaction modes. The t-test results showed a statistical significance between ACKMS and VCKMS regarding user satisfaction (t_{38}=5.5, CV=2.02, P<0.05), count of mouse clicks (t_{23}=17.9, CV=2.03, P<0.05), and count of visited pages (t_{19}=26.8, CV=2.09, P<0.05). The difference was also found significant between MCKMS and VCKMS regarding user satisfaction (t_{38}=4, CV=2.02, P<0.05), mouse clicks (t_{29}=14.1, CV= 2.045, P<0.05), and visited pages (t_{20}=26.2, CV= 2.09, P<0.05). In addition, the difference between ACKMS and MCKMS has failed to reach a statistical significance with regard to user satisfaction (t_{35}=1.2, CV=2.02, P>0.05) and the count of visited pages (t_{30}=1.8, CV=2.09, P>0.05), but it was significant regarding the count of mouse clicks (t_{31}=4.4, CV=2.07, P<0.05).

Efficiency analysis required further considerations related to task complexity and CKM styles. Fig. 4 shows the mean values of count of mouse clicks (a) and visited pages (b) according to CKM style and task complexity using the VCKMS, MCKMS, and ACKMS experimental systems. At a glance, it can noticed that ACKMS users visited relatively as many pages as their counterparts who used the MCKMS, but clicked on pages of ACKMS less frequently than MCKMS and VCKMS users.

A. Count of Clicks

In Fig. 4 (a), it can be seen that the average count of mouse clicks required to finish tasks using ACKMS was lower than that for MCKMS and VCKMS. In CKM style, levels and trends of the number of mouse clicks varied between ACKMS, MCKMS, and VCKMS in the three styles. In product selection tasks, the mean value for ACKMS was slightly lower than that for MCKMS, and just half that for VCKMS. In co-production tasks, the average count of mouse clicks for ACKMS was 19% and 42% lower than for MCKMS and VCKMS respectively. The variance was also found in the three task complexity levels. In simple tasks, the mean value of mouse clicks for ACKMS was slightly lower (9%) than that for MCKMS. The variance rose, however, to 43% in the comparison between ACKMS and VCKMS with regard to simple task performance. In moderate and complex tasks, the average count of mouse clicks for ACKMS was slightly lower (16%) than that for MCKMS, and over half that for VCKMS (moderate=54%, Complex=59%). In brief, the multimodal platforms required lower number of mouse clicks in order to complete tasks of different CKM styles and increasing complexity.

The t-test results showed a significant difference in count of clicks between ACKMS and MCKMS regarding simple (t_{32}=2.2, CV=2.03, P<0.05), moderate (t_{32}=2.4, CV=2.03, P<0.05), complex (t_{36}=5.5, CV=2.02, P<0.05), COC (t_{30}=2.8, CV=2.042, P<0.05), non-COC (t_{31}=3.1, CV=2.03, P<0.05), and co-production tasks (t_{38}=3.9, CV=2.02, P<0.05). In addition, the difference between ACKMS and VCKMS was significant in simple (t_{25}=12.6, CV=2.03, P<0.05), moderate (t_{27}=11.9, CV=2.05, P<0.05), complex (t_{22}=16.6, CV=2.07, P<0.05), COC (t_{21}=16.6, CV=2.08, P<0.05), non-COC (t_{25}=15.9, CV=2.03, P<0.05), and co-production tasks (t_{32}=9.2, CV=2.03, P<0.05). Furthermore, the difference between MCKMS and VCKMS was significant in simple (t_{33}=10, CV= 2.04, P<0.05), moderate (t_{36}=8.7, CV=2.03, P<0.05) complex (t_{23}=14, CV= 2.07, P<0.05), COC (t_{26}= 14.4, CV= 2.04, P<0.05), non-COC (t_{34}=12.1, CV=2.03, P<0.05), and co-production tasks (t_{33}=6.1, CV=2.07, P<0.05). Not only that, the ANOVA results showed that the difference in mouse clicks was significant regarding simple (F=104.2, CV=3.16, P<0.05), moderate (F=82.5, CV=3.16, P<0.05), complex (F=221.2, CV=3.16, P<0.05), COC (F=216.9, CV=3.16, P<0.05), non-COC (F=157.5, CV=3.16, P<0.05), and co-production tasks (F=50.1, CV=3.16, P<0.05). In summary, using multimodal metaphors significantly reduced the average number of mouse clicks needed to complete tasks of different CKM styles and increasing complexity.

B. Count of Visited Pages

In Fig. 3 (b), it can bee noticed that the variation between the three systems was relatively lower in the average number of visited pages, compared to count of mouse clicks, due to its insensitivity to task nature and requirements. In CKM styles, it can be seen that the variation in the number of pages visited was found in product selection tasks, whereas levels of this variable was constant in co-production tasks. In product selection tasks, the mean value of visited pages for VCKMS was over fivefold that for ACKMS and MCKMS, whereas the variance between ACKMS and MCKMS fell in a narrow range from 7% to 8%. In task complexity, the mean value of visited pages for using ACKMS was relatively equivalent to that for MCKMS in all task complexity levels. However, the average number of visited pages for using the multimodal platforms was considerably reduced, compared to VCKMS. In fact, the mean value for ACKMS was 70%, 86%, and 87% lower than that for VCKMS with regard to the performance of simple, moderate and complex tasks respectively. In simple tasks, it can be noticed that the mean value for MCKMS was just third that for VCKMS, while in moderate and complex tasks, the mean value for MCKMS was one-seventh that for VCKMS. In summary, the count of pages visited during the interaction with ACKMS dropped considerably, compared to that for VCKMS. However, MCKMS users visited as many pages as their counterparts who used ACKMS, because patterns of the user's navigation were relatively identical in the multimodal systems.

The t-test results showed that the difference in count of visited pages between ACKMS and MCKMS was insufficient regarding the performance of simple (t_{37}=1.9, CV=2.02, P>0.05), moderate (t_{38}=1.1, CV=2.02, P>0.05), complex (t_{32}=1.1, CV=2.03, P>0.05), non-COC (t_{36}=1.5, CV=2.02, P>0.05), and co-production tasks (t_{38}=0.74, CV=2.03, P>0.05). However, the difference was found significant in COC tasks (t27=2.1, CV=2.05, P<0.05). In addition, the variance in count of visited pages between ACKMS and VCKMS was found significant in COC (t_{27}=25.9, CV=2.093, P<0.05), non-COC (t_{20}=22.4, CV=2.086, P>0.05), simple (t_{22}=18.2, CV=2.07, P<0.05), moderate (t_{19}=17.2, CV=2.09, P<0.05), and complex tasks (t_{32}=16.9, CV=2.09, P<0.05). However, it has failed to reach a statistical significance as regards co-production tasks (t_{36}=0.85, CV=2.02, P>0.05). Furthermore, the difference in count of visited pages between MCKMS and VCKMS was found significant with regard to the performance of COC (t_{26}=14.4, CV=2.04, P<0.05), non-COC (t_{34}=12.1, CV=2.03, P>0.05), simple (t_{33}=10, CV=2.04, P<0.05), moderate (t_{36}=8.7, CV=2.03, P<0.05), and complex tasks (t_{23}=14, CV=2.07, P<0.05). However, it was insufficient in co-production tasks (t_{28}= 0.9, CV=2.05, P>0.05). Moreover, the one-way ANOVA results suggested that the difference in visited pages was significant regarding the performance of simple (F=289.4, CV=3.16, P<0.05), moderate (F=293.8, CV=3.16, P<0.05), complex (F=278.3, CV=3.16, P<0.05), COC (F=646.8, CV=3.16, P<0.05), non-COC tasks (F=481.1, CV=3.16, P<0.05). However, it has failed to reach a statistical significance as regards co-production tasks (F=0.4, CV=3.16, P>0.05). In few words, patterns of user navigation showed that the three groups visited the same number of pages during the co-production tasks. However, using multimodal metaphors has shown to be positively related to the reduction in the average number of visited pages required for product selection tasks.

VI. Conclusion

The role CKM has become increasingly important to public and private organisations, due to the cost savings it offers. However, it is considerably complex, vague, and challenging discipline, due to the many aspects it involves. This study shed light into three challenges to E-CKMS (knowledge hoarding, trust, and information overload), which can be addressed by using multimodal metaphors. This hypothesis was examined empirically by three independent groups taking part in the evaluation of three E-CKMS experimental platforms. It was noticed, during the course of experiment, that the multimodal conditions has demonstrated to be useful for improving user performance, particularly regarding tasks of different CKM styles, and increasing complexity. The utilisation of expressive avatars has been shown to have a considerable influence on the generation of positive feelings, emotions, and beliefs. Overall, subjects were satisfied, and expressed interest in the use of multimodal interaction metaphors. Results showed that the use of multimodal metaphors in E-CKMS was more efficient with regard to count of mouse clicks and visited pages, compared to the text with graphics. In fact, navigational behaviour for using ACKMS showed as similar patterns as that for MCKMS, because both were multimodal systems, and relied on assessing information and knowledge from a single point of contact, as opposed to VCKMS. Of course, the difference in efficiency between the conditions has a considerable effect on user satisfaction. Therefore, it can be concluded that the use of multimodal metaphors has contributed positively towards the improvement of E-CKMS efficiency and user satisfaction.

VII. Future work

This experiment revealed that using multimodal metaphors to communicate customer knowledge has shown to be useful in terms of efficiency and user satisfaction. However, there was a potential effect of user experience, as it was controlled during the course of this experiment. Hence, a further investigation is needed to examine the influence of multimodal metaphors on experienced user performance and satisfaction, as opposed to inexperienced users. Moreover, the nature of between-subjects experimental design affects user attitudes, because the design lacks three major factors. First, it does not provide the user with choices to rank the most preferred interface, because each user group was exposed to one condition only. Therefore, it can be considered as vital to allow users to view multiple conditions in order to rate perception of usefulness and benefit of an approach, as opposed to another method. Secondly, the measure of user performance took place under different usability and complexity conditions, which logically has an influence on user attitudes. Therefore, the complexity and usability influences needs to be controlled and kept at the minimum levels. Finally, the experiments dealt with the user satisfaction in a vague manner, failed to include all satisfaction aspects Therefore, measuring user attitudes towards using the three interaction modes in larger and more comprehensive scales merits further investigation.

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