The role of avatars with facial expressions to communicate customer knowledge

Mutlaq B. Alotaibi and Dimitrios I. Rigas

***Abstract*—** This paper describes a comparative evaluation study conducted to examine the impact of incorporating avatars with facial expressions into Electronic Customer Knowledge Management Systems (E-CKMS) on usability of E-CKMS, and the user's attitudes and knowledge. Although the implementation of E-CKMS encounters several challenges, such as lack of trust and information overload, few empirical studies were devoted to examine the role of metaphors of audio-visual nature. As a result, an empirical investigation was carried out by implementing avatars-enhanced multimodal E-CKMS (ACKMS), and comparing it with text with graphics E-CKMS (VCKMS), and another multimodal E-CKMS (MCKMS) that utilises speech, earcons and auditory icons. The three experimental systems were evaluated by three independent groups of twenty users each (n=60) performed eight common tasks, increasing in complexity and designed based on three different styles of Customer Knowledge Management (CKM). Results and analysis revealed that ACKMS outperform MCKMS and VCKMS with regard to the user's attitudes and knowledge.

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

I. INTRODUCTION

HARNESSING intangible assets is regarded as one of the primary sources of creating, and sustaining superior performance in the age of knowledge [1]. Knowledge, as a concept, covers a vast area of various taxonomies, principles, levels, and views. knowledge can be categorised based on the source of elicitation into internal and external knowledge [2]. External knowledge or Customer Knowledge (CK) is elicited from beyond the organisational boundary, during the customer-company interaction [3], under a great deal of time pressure [4], and regarded as the most valuable type of knowledge [5]. However, the lack of customer willingness to share knowledge [6] is a common CK elicitation issue that can be alleviated by incorporating multimedia systems [7], and interactive components. Although the potential of multimodal interaction is well recognised, empirical studies that evaluate this role is generally lacking in the current literate to Customer Knowledge Management (CKM).

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This paper describes an empirical investigation carried out to assess the effect of incorporating multimodal interaction metaphors into Electronic Customer Knowledge Management Systems (E-CKMS) interfaces on the user's attitudes and knowledge, as a part of a comprehensive study that evaluated effectiveness [8], and efficiency [9] of this approach, as well as user satisfaction [10]. In order to achieve the research aims, two experimental platforms were implemented (Multimodal), and compared to a control one (text with graphics) in terms of the user's attitudes and knowledge. The paper contributes to the literature to CKM, especially to the manner in which knowledge is communicated to the customer, and introduces CKM as a new application domain of audio-visual metaphors. This paper is an extended version of an earlier conference paper that evaluated the influence of avatars on the user's trust and knowledge [11]. The remainder of the paper is organised in six sections. In Section 2, draws current knowledge on three key themes: CKM, trust and customer interaction. Section 3 describes the three E-CKMS experimental platforms. Design of the empirical study is presented in Section 4. In Section 5, we presented analysis and discussion of results. Conclusion is provided in Section 6. Finally, we describe future work in Section 7.

II. CUSTOMER KNOWLEDGE MANAGEMENT

CK can be best described as "*the dynamic combination of experience, value, scenario information and expertise, insight which is needed, created and absorbed during the process of transaction and exchange between the customers and the enterprise*" [12]. CK is categorised into three basic types: knowledge for customer (prepared inside the company), Knowledge about customer (discovered by the powerful analytical systems), and knowledge from customer (customer expectations) [12]. Knowledge from customers can be gathered via feedback mechanisms (e.g. customer reviews and ratings), which is provided by customers for peer customers, and introduced by web-based retailing systems, such as Amazon.com [13]. This type of CK develops through the constant use of products, which may include knowledge about products provided by competitors [12], and it is vital for product development and innovation [14]. In addition, Gibbert et al. [7] proposed the five styles of CKM that included Communities of Customers (COC) and co-production, and introduced lack of trust as an issue that can be addressed by interactive multimedia cues.

A. Communities of Customers (COC)

Amazon.com can be regarded as a typical example of COC, which are deeply rooted in the traditional Knowledge Management (KM) [6]. COC facilitates CKM by establishing a knowledge sharing space, which included ratings and reviews, for customers [7]. Experienced customers tend not to share (knowledge hoarding), due to the fear of losing power or intellectual rights, but they can be encouraged to do so by means of intensives or multimedia solutions [15]. Besides the KM aspects, the COC context involved Customer Relationship Management (CRM) ones, in which CRM components analyse customer buying behaviour in order to leverage selling opportunities (up-selling and cross-selling) [16]. In brief, Amazon.com introduces knowledge obtained from CRM analytical components (recommendations), knowledge elicited by means of KM (ratings and reviews), and product information [17].

B. Co-Production

Co-production can be seen as another CKM style (derived from KM) that allows customers to participate in the New Product Development (NPD) process, by proposing products, and then testing them. Electronic Products (E-Products), in particular, do not require a complete line of production, in which the customer may experience repeated shifts from production lines to customer care departments and visa-versa [18]. Instead, E-Products requires only a software [6] to be produced, such as the open source software and user innovation communities [19] (see Microsoft case study [13]). More recently, Etgar [20] argued that co-production is linked to customisation, which reflects customer intimacy and one-to-one marketing aspects. Etgar presented four co-production outstanding issues, alongside with a theoretical model that addresses them. Decision of customer engagement in co-production is among these issues, and it requires trust in the first place.

C. Trust

Trust is an important aspect of E-Business [21] settings, due to the lack of interpersonal interaction (face-to-face), and formal assurance (printed receipts) typically found in traditional retailing [22]. 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 [23]. It has been argued that behavioural trust is influenced by cognitive trust, and measuring both components is regarded as redundancy [23]. 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 [24]. 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 [12]), and honesty (beliefs of the partner desire to keep promises) [22]. In the context of CKM, lack of customer trust was raised as an issue in customer loyalty (CRM aspect) [12, 23], knowledge sharing [15] (KM function), E-CKMS [7], and even in face-to-face CKM [25].

D. Customer Interaction

Interactive technologies that produce high levels of social presence plays a crucial in improving users' perception of trust [26]. In E-Business contexts, trustworthy web-based systems should introduce a set of features that compensate the absence of skilful sale representatives [27], who can establish a persuasive communication of product information. In the literature to interactive multimodal interfaces, information was conveyed visually (text with graphics [28]), vocally (speech recognition [29]), aurally (speech and non-speech sounds [30]), or by combining speech with other modalities (e.g. facial expressions and body gestures [31]). Synthesis and recoded speech, in particular, represent the speech sounds utilised, whereas earcons [32] and auditory icons [33] used as non-speech sounds. Earcons can be defined as abstract sounds produced by instruments to convey single value, and once it was communicated, the only reference to it is the user's memory [32]. Auditory icons [33] simulates natural sounds derived from the surrounding environments to convey the occurrence of events, and users are usually familiar with it, due to its metaphorical nature. In addition, facial modalities utilises human-like characters, which reflect higher levels of social presence, and convey verbal and non-verbal information by means of speech and facial expressions [34] (e.g. happy, sad, neutral).

III. EXPERIMENTAL PLATFORM

The E-CKMS experimental platform presented knowledge and information usually found in web-based retailing systems, alongside with two CKM styles (COC and co-production). In the COC context, four basic categories of knowledge were communicated including trends (e.g. best and worst rated), customer reviews, customer ratings, and website advices (e.g. recommended, not recommended, top or least recommended products). Furthermore, co-production components enable an experimental NPD for E-Products (billing schemes) by offering a trial-and-error mechanism. The platform was implemented with three different interfaces: text with graphics only (VCKMS), multimodal that utilised speech, earcons, and auditory icons (MCKMS), and multimodal with natural recorded speech, earcons, and enhanced by human-like avatars (ACKMS). Metaphors used in these platforms were text, graphics, speech, earcons (including timbre, rhythm, and rising pitch), auditory icons, special effects, and facial expressions. Detailed information about the association between categories of CK and the metaphors used in each interface is presented in Appendix B.

In order to implement multimodal user interfaces, several technologies was utilised, such as text-to-speech engine, speech agent, and sound recording software [35]. Furthermore, environmental sounds [33] was introduced, such as sound of *typing, cheering, clapping, laughing, gasping, foghorn, side*

whistle, and camera shot. In addition, earcons were created using multi-timber synthesiser software [36], and based on guidelines provided by Brewster [37]. Timbre, for instance, was utilised to differentiate first level of families of earcons (e.g. *guitar, violin, trumpet, drum, organ, and piano*) [38], and rhythms to differentiate the second level. Furthermore, facial modalities were employed to convey different types of CK, alongside with speech, and categorised based on the nature of facial expression into positive, negative, and neutral expressions. Eight of the most popular expressions [39] were selected and employed including three positive (*happy, positively surprised, and amazed*), three negative (*sad, tired/bored, and disgusted*), and two neutral (*neutral and thinking*). The illustrations of facial expressions are presented in Appendix A.

A. Product Catalogue Implementation

The product catalogue was implemented as typical tabular one, and assumed that VCKMS presents 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 allow 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 plays a sequential combination of environmental sound, speech, and rising pitch metaphors to communicate knowledge and information about the product and trends of customer opinions. Similarly, the same button is provided in ACKMS product catalogue, but it plays a video clip that presents a presumed sales representative who introduces the product features orally, and conveys knowledge about trends of customer opinions emotionally, alongside with earcons playing in the background to communicate 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 allows repetitive NPD until the final design is reached via trail-and-error engine that stimulates the billing process. The customer manipulates billing scheme parameters, such as monthly rental, free minutes and free tests, and invokes a billing engine, which then provides customised bill (trial). The trial is stored in a trial comparison array to facilitate trials comparison, and hence support 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 trail comparison information (see Appendix A). Similar to the product catalogue approach, the comparison information was presented by auditory stimuli, and expressive avatar in MCKMS and ACKMS respectively.

TABLE 1 DESIGN OF EMPIRICAL STUDY

	Task complexity		
CKM Style	Simple	Moderate	Complex
COC	T1	T3	T6
Post-task	Achievement Test (4 questions)		
No CKM Style	T2	T4	T7
Co-Production		T5	T8
Post-experimental	Attitude Statements (10 items)		

IV. DESIGN OF EMPIRICAL STUDY

Sixty participants (all were students at University of Bradford, and regular internet users) were assigned randomly to three groups (n=20 each) based on the non-probability sampling, in which the probability of selecting an individual is unknown, and convenience-sampling method [40], which targets captive audience. Participants were instructed to use the three system versions independently, by performing eight common tasks of three different CKM styles (COC, No CKM style, and Co-production), increasing in complexity. In COC tasks (T1, T3, and T6), subjects were provided with a product selection scenarios in the presence of COC context, whereas in the tasks that do not involve a CKM style (T2, T4, and T7) users were required to select products in the absence of COC. In co-production style, the user was required to participate in the NPD process that produces E-Products (billing schemes). Tasks of each style were designed in an increasing complexity: simple, moderate, and complex. More information about tasks design is provided in Appendix C. Upon the completion of all tasks, subjects were instructed to fill in a questionnaire devised to measure aspects related to the user's attitudes using six-point Likert scale [41] ranging from agree strongly (6) to disagree strongly (1). Table 1 illustrates the design of this empirical study, but the order of tasks was counterbalanced between users in order neutralise possible task learning effect.

Aspects of the user's attitudes included ten statements related to user's satisfaction and perception of trust. The satisfaction measurement consisted of five statements focusing on items related to ease of the system use (EOU), extent of the user's confusion (EOC), extent of the user's frustration (EOF), ease of navigation (EON) and overall comfort (COM). Similarly, five statements were presented to measure aspects of users' perception of trust including match of user expectations (MOX), honesty of the vendor (HOV), the effect of previous experience (EPE), incompetency of the vendor (ICV), and the trustworthiness of the vendor (TOV). Subjects were required to rate each statement, and upon the completion of the user rating, a scoring technique labelled as the system usability scale (SUS) [42] was applied to generate the overall score. Furthermore, achievement test was administrated to assess level of knowledge, by assessing memorability, understanding, and utilisation of knowledge presented during the task performance. This involved designing a researcher-made multiple-choice test [43] consisted of four sections, in which the user was provided with a set of questions, and asked to select the correct answers among several alternatives.

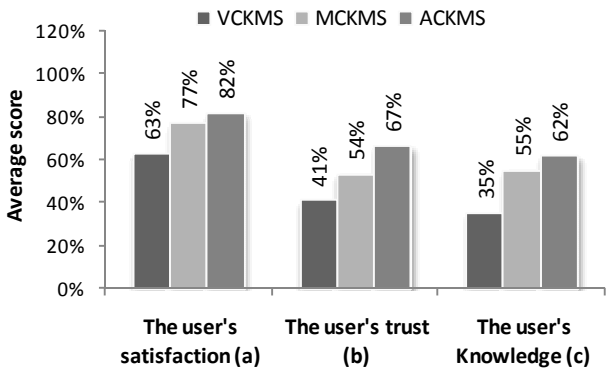


FIG.1 MEAN VALUES OF THE USER'S SATISFACTION (A), TRUST (B), AND KNOWLEDGE (B) WITH THE VALUES FOR USING THE VCKMS, MCKMS AND ACKMS EXPERIMENTAL SYSTEMS

V. RESULTS AND DISCUSSION

Fig. 1 shows mean values of the user's satisfaction (a), trust (b), and knowledge (c) using the VCKMS, MCKMS, and ACKMS experimental systems. At first glance, it can be seen that the user's knowledge and perception of trust shows relatively a similar picture with regard to the variance between the three E-CKMS interaction modes, whereas users of the two multimodal E-CKMS showed the same level of satisfaction, which was by far greater than that for the text with graphics E-CKMS. In Fig. 1 (a), users of interaction mode 3 (ACKMS) showed a similar satisfaction felling as users of interaction mode 2 (MCKMS), as the variance between the two modes did not exceed 6%. In addition, the average satisfaction score for interaction mode 1 (VCKMS) was just three-quarters that for interaction mode 3. Results obtained from t-test [44] suggested that the difference in user satisfaction was significant between interaction mode 1 and 3 (t_{38}= 5.5, CV= 2.02, P < 0.05), but that between interaction mode 2 and 3 failed to reach statistical significance (t_{35}= 1.2, CV= 2.02, P > 0.05). In Fig. 1 (b), the average score of the user's trust rose steadily from interaction mode 1 to mode 3 by 13%. In Fig. 1 (c), levels of the user's knowledge showed relatively the same picture, as the mean value rose dramatically from interaction mode 1 to mode 3.

The t-test results showed that the difference between interaction mode 1 and 2 has reached statistical significance with regard to the user's trust (t_{25}=4, CV=2.06, P<0.05), and knowledge (t_{37}=8, CV=2.02, P <0.05). It also showed a significant difference between interaction mode 2 and 3 regarding the user's trust (t_{33}=3.8, CV=2.03, P<0.05), and knowledge (t_{35}=2.9, CV=2.03, P<0.05). Furthermore, the difference between interaction mode 1 and 3 was found significant as regard the user's trust (t_{31}=11.4, CV=2.03, P<0.05), and knowledge (t_{37}=12.4, CV=2.03, P<0.05). Additionally, the one-factor ANOVA [45] results suggested that the difference between the three interaction modes was found statistically significant with regard to the user's satisfaction (F=15.5, CV=3.16, P<0.05), trust (F=36.4, CV=5, P <0.01), and knowledge (F=71.3, CV=5, P<0.01).

TABLE 2 THE MODE AND MEAN VALUES OF THE FIVE SATISFACTION ASPECTS, AS WELL AS THE FREQUENCY OF THE MODE

Group	Value	Aspects of satisfaction				
		EOU	EOC	EOF	EON	COM
VCKMS	Mode	4	3	3	5	5
	Freq.	80%	55%	65%	95%	100%
	Mean	3.85	3.45	3.10	4.95	4.45
MCKMS	Mode	5	2	2	5	5
	Freq.	90%	70%	70%	80%	85%
	Mean	4.80	2.20	2.20	5.00	4.95
ACKMS	Mode	6	2	1	6	6
	Freq.	100%	50%	50%	100%	100%
	Mean	5.25	2.85	1.70	5.35	5.40

In brief, it can be said audio-visual E-CKMS contributes remarkably to the improvement of the user's satisfaction, trust and knowledge, compared to text with graphics.

A. The User's Satisfaction

Table 2 shows the mode and mean values, as well as the frequency of the mode, of user satisfaction items, with the values for using the three interaction modes. At first glance, a strong agreement among all users indicated that interaction mode 3 was easy to use, ease to navigate through, and overall comfortable, but there were times during the interaction where half of the users have felt that it confusing and frustrating. In particular, all ACKMS users agreed strongly that it was easy to use, in compassion with 90% of MCKMS users who agreed moderately, and 80% of VCKMS users who agreed slightly. Additionally, half of ACKMS users disagreed moderately that there were times where they felt confused, compared to 70% of MCKMS users who disagreed moderately, and 55% of VCKMS users who disagreed slightly. Furthermore, it can be noticed that half of ACKMS users disagreed strongly that the system felt frustrating, compared with 70% of MCKMS users who disagreed moderately, and 65% of VCKMS users who disagreed slightly. It was noteworthy also that the mode values of ease of navigation and overall comfort showed relatively the same figures. All ACKMS users agreed strongly that it was easy to navigate and felt generally comfortable, compared to moderate agreements of MCKMS users about both ease of navigation (85%), and general fell of comfort (80%), as well as VCKMS users about ease of navigation (95%), and overall comfort (all the users). In addition, the difference between interaction mode 3 and mode 2 was examined using Mann-Whitney statistical test [46] with regard to the five aspects of user satisfaction. The difference failed to reach statistical significance regarding EOU (U=140, CV=127, P>0.05), EOC (U=131, CV=127, P>0.05), and EON (U=141.5, CV=127, P>0.05), but it was found significant as regard EOF (U=127, CV=127, P< 0.05), and COM (U=121, CV=127, P<0.05). On the other hand, the difference between interaction mode 3 and mode 1 reached statistical significance in EOU (U=140, P < 0.05), EOC (U=131, P < 0.05), EOF (U=127, P<0.05), EON (U=141.5, P<0.05), and COM (U=121, P<0.05).

TABLE 2 THE MODE AND MEAN VALUES OF THE FIVE TRUST ASPECTS, AS WELL AS THE FREQUENCY OF THE MODE

Group	Value	Aspects of trust				
		MOX	HOV	EPE	ICV	TOV
VCKMS	Mode	4	5	6	4, 5	3
	Freq.	75%	75%	50%	45%	75%
	Mean	3.70	3.60	5.40	3.65	3.05
MCKMS	Mode	4	5	5	4	4
	Freq.	55%	50%	30%	45%	50%
	Mean	4.10	3.55	4.20	2.90	3.85
ACKMS	Mode	6	5	3	4	4
	Freq.	60%	80%	56%	50%	45%
	Mean	5.60	3.85	3.30	3.05	4.55

In addition, the variance between the three modes of interaction was found significant, according to Kruskal-Wallis results [46], with respect to EOU ($H=22$, $DF=2$, $P<0.01$), EOC ($H=15.2$, $DF=2$, $P<0.01$), EOF ($H=16.9$, $DF=2$, $P<0.01$), EON ($H=6.8$, $DF=2$, $P<0.05$), and COM ($H=15.8$, $DF=2$, $P<0.01$). In summary, it can be said that interaction mode 3 was more satisfactory than mode 1 with regard to all user satisfaction factors. However, the satisfaction figures for ACKMS and MCKMS appeared to be relatively similar only in statements related to ease of the system use, extend of confusion, and ease of navigation.

B. The User' Trust

Table 2 shows the mode and mean values of trust aspects with the values for using the three interaction modes, as well as the frequency of the mode. Overall, it can be seen that the three modes differ greatly with respect to aspect of users' perception of trust, apart from users' perception of the vendor honesty. Users' responses suggested that ACKMS matched what was expected (MOX) by users more than the other two conditions (MCKMS and VCKMS), because 60% agreed strongly that the expectations were matched by ACKMS, whereas 75% and 55% agreed slightly in VCKMS and MCKMS respectively. In addition, the mean value of the effect of previous experience (EPE) decreased remarkably from interaction mode 1 to mode 3, as MCKMS and ACKMS users tended to utilise contents provided by each condition more than their own experience with products, in comparison with VCKMS users. This result supported the observation that the user's knowledge increased from interaction mode 1 to 3, and suggested that metaphors of audio-visual nature positively affected the memorability, understanding, and utilisation of knowledge. Furthermore, the mean values of perceived incompetency, and honesty of the vendor differed slightly between the three conditions, whereas the mean values of perceived trustworthiness of the vendor rose steadily from mode 1 to mode 3, by approximately (0.8). In Particular, it can be seen that 45% of VCKMS users agreed slightly and moderately that the vendor was unprofessional and incompetent, compared to 45% and half of the sample agreed slightly in MCKMS and ACKMS respectively. In the three conditions, most of the users agreed moderately that vendor gave the impression that it was upright and honest, but with different percentages (VCKMS=75%, MCKMS=50%, and ACKMS= 80%). Furthermore, the mean value of perceived trustworthiness of the vendor rose steadily (by 26% from interaction mode 1 to 2, and 20% from mode 2 to 3). In particular, 75% of VCKMS users disagreed slightly that the vendor gave the impression that it was trustworthy, whereas half of MCKMS and 45% of ACKMS users agreed slightly.

Regarding the aspects of trust, the difference between pairs of interaction modes, and between the three interaction modes was examined by Mann-Whitney and Kruskal-Wallis statistical tests [46] respectively. According to Mann-Whitney results, the difference between ACKMS and MCKMS failed to reach statistical significance in ICV ($U=178$, $CV=127$, $P>0.05$), and HOV ($U=146$, $CV=127$, $P>0.05$), but it was found significant in MOX ($U=24$, $CV=127$, $P<0.05$), EPE ($U=109.5$, $CV=127$, $P<0.05$), and TOV ($U=113.5$, $CV=127$, $P<0.05$). In contrast, the significant difference between ACKMS and MCKMS was found in MOX ($U=0.0$, $CV=127$, $P<0.05$), EPE ($U=131$, $CV=127$, $P<0.05$), ICV ($U=127$, $CV=127$, $P<0.05$), HOV ($U=141.5$, $CV=127$, $P<0.05$), and TOV ($U=121$, $CV=127$, $P<0.05$). Furthermore, the Kruskal-Wallis results showed a significance variance in MOX ($H=40$, $DF=2$, $P<0.01$), EPE ($H=29.6$, $DF=2$, $P<0.01$), ICV ($H=9.7$, $DF=2$, $P<0.05$), and TOV ($H=27$, $DF=2$, $P<0.01$), but not in HOV ($H=3.2$, $DF=2$, $P>0.05$). In brief, the variance between the three conditions was found significant in all aspects of trust investigated in this study, apart from perceived honesty of the vendor.

C. Discussion

During the experiment phase, it was noteworthy that ACKMS users were generally capable to complete tasks of different CKM styles, and increasing complexity significantly better than VCKMS and MCKMS users. The presence of avatars with facial expressions has been shown to be the key factor in the generation of positive feelings that have been linked to various considerable outcomes, such as increased user confidence, improved interface friendliness, and perceived trustworthiness. Users appeared to be more confident, showing higher levels of content understanding, and devoting less mental work, due to their exposure to a human-like character that speaks, and expresses several emotions simultaneously. In addition, as the attractiveness of expressive avatars cannot be ignored, all ACKMS users felt that the system was obviously very intelligent and had a pleasant appearance. Another reason behind this attractiveness is the novelty of this approach, and the perceived consistency between the avatar verbal and non-verbal communications. In addition, it is becoming evident that incorporating expressive avatars into E-CKMS interface has, to some extend, compensated the absence of interpersonal interaction, and has been shown to be particularly useful to build and retain trust, due to the lack of human warmth and sociability in the traditional E-CKMS. To conclude, the social aspects of expressive avatars led to several positive emissions, which have showed to be particularly contributing towards the improvement of user engagement on CKM related activities, and the promotion of the user-website interaction.

VI. Conclusion

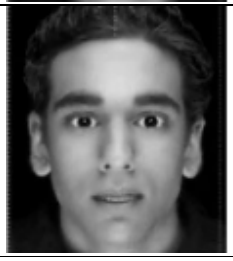
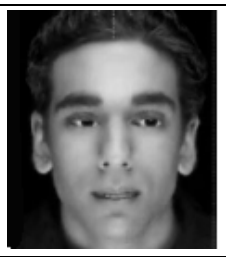
This paper explored the role of audio-visual metaphors in E-CKMS in terms of the user's attitudes and knowledge. E-CKMS environments encounters lack of trust and knowledge hoarding, but implementing audio-visual E-CKMS interfaces had the potential to address these issues, as this approach has demonstrated to be useful in other disciplines. This hypothesis was investigated, and the experience gained the investigation suggested that knowledge memorability, understanding, and utilisation could be improved by enhancing textual and graphical representation of knowledge with metaphors of audio-visual nature. In addition, user responses obtained from statements related to the user's attitudes provided insights into the significance of multimodal interaction in improving users' satisfaction and perception of trust, since the highest scores were associated with interfaces that utilised multimodal metaphors. In particular, it is becoming evident that incorporating facial modalities, alongside with speech and earcons into E-CKMS interfaces has a positive effect on users' perception of trust, due the role of its social presence, in comparison with interfaces that incorporated speech, earcons, and auditory icons. Therefore, it is essential to designers of E-CKMS interface to be aware of the potential of, and foster multimodal interaction, not as an alternative approach to the visual communication of knowledge, but as a complementing method.

VII. Future work

This experiment revealed that incorporating interactive metaphors into E-CKMS has demonstrated to be useful with regard to the user's attitudes and knowledge, but users' experience had a potential effect, as it was controlled during the course of this experiment. Hence, a further investigation is needed to examine the role of interactive multimodal metaphors in enhancing the user's attitudes and knowledge with experienced users, compared with inexperienced ones. In addition, due to the nature of between-subjects experimental design, the design lacked three major factors. First, users could not choose the most preferred interface because each group of users has examined only one version. It is vital for users to view more than one interface in order to rate the perceived usefulness and ease of use for an approach, in comparison with the other one. Secondly, the performance of users was measured in different usability and complexity levels, which naturally affected the user's attitudes. Therefore, the effect of complexity and usability needs to be controlled and kept at the minimum levels. Finally, the experiments dealt with the user's satisfaction and trust in a vague manner, in which not all aspects of the user's attitudes were covered, such as cognitive and behavioural trust components, and perception of interface ease of use and usefulness. Therefore, measuring user attitudes towards using the systems in larger and more comprehensive scales merits further investigation.

Appendix A (Snapshots of the experimental systems)

Table A.1 Facial expressions categorised based on expression nature and CKM style

		CKM style		
		COC	No CKM Style	Co-Production
Expression nature	Positive	 Happy	 Amazed	 Positively surprised
	Negative	 Sad	 Tired	 Disgusted
	Neutral	 Neutral		 Thinking

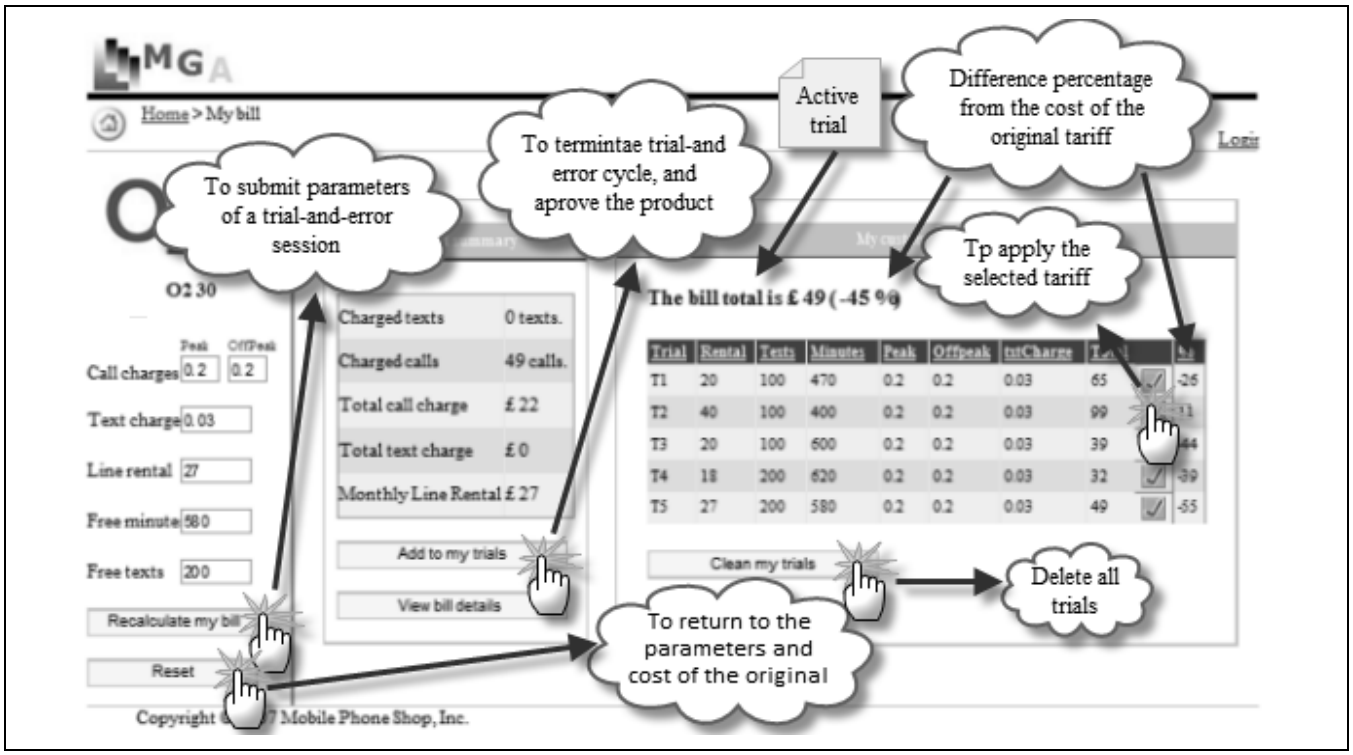


FIG. A.1 CO-PRODUCTION INTERFACE FOR VCKMS WITH TABULAR TRIALS LIST

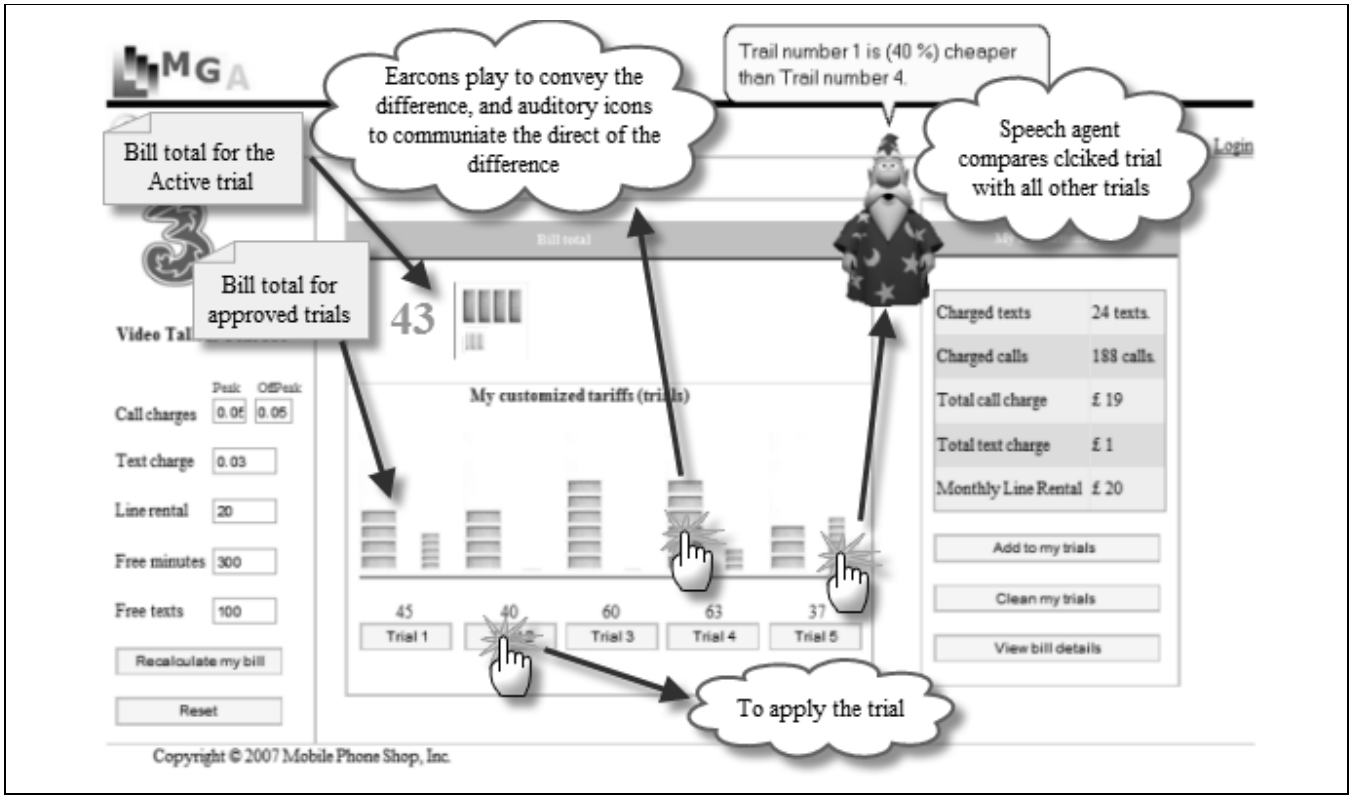


FIG. A.2 CO-PRODUCTION INTERFACE FOR MCKMS WITH GRAPHS AND MULTIMODAL METAPHORS COMMUNICATING TRIALS COMPARISON KNOWLEDGE

APPENDIX B (DIFFERENCES BETWEEN THE THREE INTERACTION MODES)

TABLE B.1 MAPPING BETWEEN TYPES OF CK AND METAPHORS IN THE VCKMS MCKMS AND ACKMS EXPERIMENTAL SYSTEMS

	E-CKMS Interaction Mode															
	VCKMS		MCKMS						ACKMS							
						Earcons							Earcons			
	Text	Graphics	Text	Graphics	Speech	Timbre	Rising pitch	Auditory icons	Text	Graphics	Visual special effect	Speech	Timbre	Rhythm	Rising pitch	Facial expressions
Trends (Top10)		√		√		√	√			√				√	√	
Best rated		√		√		√				√				√		
Worst rated						√								√		
Position in the list		√					√								√	
Customer reviews	√		√		√			√				√				√
Review content	√		√		√							√				
Writer attitude					√							√				
Trend of opinions								√								√
Average rating		√		√		√				√				√	√	
Average rating		√		√		√				√				√		
Rating value 1-5		√		√			√			√					√	
Website advice		√		√		√	√	√								
Top recommended		√		√		√				√			√			
Recommended		√		√				√		√			√			
Not recommended													√			
Least recommended								√					√			
Position in the list		√		√			√				√					
Co-production	√		√	√	√	√										√
Bill total	√			√							√					
Difference percentage	√		√			√	√					√				
Difference direction								√								√
Trials comparison					√							√				
Product information	√	√	√	√	√			√	√	√	√	√				√
Price	√		√						√							
Product features	√	√	√	√	√			√	√	√	√	√				√

APPENDIX C (SUMMARY OF TASK REQUIREMENTS AND COMPLEXITY FACTORS)

TABLE C.1 TASK REQUIREMENTS FOR PRODUCT SELECTION IN THE PRESENCE AND ABSENCE OF COC, AS WELL AS CO-PRODUCTION TASKS

1	Product selection in the presence of COC (Product type is mobile phone) tasks [1]										
		CK			Product features				CK	Complexity factors	
Task	Price	Rating	Trends	Website advice	FM	MP3	Camera	3G	Reviews	NOTR [2]	NOAS [3]
T1	<£ 82	>1				√	>1.0	√	At least 2 positive	6	18
T3			√				>0.5	√	Positive > Negative	7	8
				√			<3.0		At most one negative		
T6	>£ 25	<5		NOT	√		>1.0	NOT	Positive <= Negative	8	2
	<£ 61										

2	Product selection in the absence of COC (Product type is tariff or billing price plan) tasks [4]										
		CK			Product features			Billing information		Complexity factors	
Task		Rating	Trends	Website advice	Line rental	Free Minutes	Free texts	Bill total	Extra charges	NOTR	NOAS
T2					<£ 35	>100	>50	<£ 107		4	22
T4						>380	>50	<£ 49	√	4	9
T7						>200	<50		√	4	2
						<300					

3	Co-production tasks [5]								
Task	Trial information		Cost reduction	The cost reduction is calculated based on cost of					
	Billing trials	Trial number	Reduction range	Original tariff	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
T5	Two trials	Trial 1	20% - 30%	√					
		Trial 2	20% - 30%		√				
T8	Five trials	Trial 1	10% - 15%	√					
		Trial 2	10% - 15%		√				
		Trial 3	10% - 15%			√			
		Trial 4	10% - 15%				√		
		Trial 5	10% - 15%					√	

[1] In COC tasks, the user was provided with phone selection scenarios that reflect the task requirements shown in T1, T3, and T6. It can be seen that at least one task requirement was included from the COC domain.

[2] NOTR denotes the number of task requirements need to be fulfilled in order to regard the tasks a successfully completed.

[3] NOAS denotes the number of available product selections that when one of them was selected, the task is regarded as successfully completed.

[4] In (No CKM style) tasks, the user was provided with tariff selection scenarios that reflect the requirements shown in T2, T4, and T7. It can be seen that there is no task requirement was included from the COC domain.

[5] In co-production tasks, the user was instructed to perform few billing trials to produce customised schemes as shown in T5 and T8. It can be seen that the more trial the user performs, the more complex the task becomes.

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