Multimodal Metaphors for Edutainment in E-Learning Interfaces: A Usability Evaluation of Learnability and Experienced User Performance

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Abstract—**This paper aimed to comparatively analyze two methods of Electronic Learning (E-learning), in which avatars were utilized as virtual lecturers, with a particular focus on measuring learnability and Experienced User Performance (EUP). Insight has been provided into E-learning motivations and guidelines within the area of edutainment. Research into the communication of educational materials has also been included to provide explanations into the different edutainment techniques and factors influencing E-leaning performance. An E-learning environment was designed and constructed based on pedagogical principles. Emphasis was placed on the significance of multimodal interaction metaphors, as a means of improving learning skills. An empirical study was conducted to compare two E-learning approaches: avatars as pedagogical agents and E-learning through edutainment. The study was divided into two experiments: learnability and EUP; of which, two groups were instructed to interact with the experimental platforms under two conditions: first-time-use and frequent-use. The results of the experiments showed a statistical significance in favor of EUP in E-learning through edutainment.**

Index Terms—**edutainment, multimodal metaphors, avatars, learnability, experienced user performance (EUP)**

I. Introduction

The increasing demand of online learning and learners has called for the traditional design of E-learning interfaces to be expanded beyond the focus of the traditional visual channel, to incorporate not only interactive metaphors but also entertainment elements. Edutainment is an important factor associated with improving learning outcomes, because it includes entertainment as a supporting part of education to alleviate students' boredom and increase enthusiasm and engagement [1]. One of the edutainment techniques is the utilization of games for E-learning; these are particularly supplemented with interactive multimodal metaphors, which have been proven to be usable in many experiments [2-5]. However, the incorporation of multimodal edutainment elements in E-learning interfaces should be approached with extreme care and with compliance to the empirically derived guidelines for edutainment in E-learning interfaces [6].

This paper has undertaken an empirical investigation into interactive E-learning systems by focusing on the effect of frequent-use on the performance of online learners. In the related E-learning studies, the experiments aimed to evaluate the performance of novel learners who were using experimental E-learning platforms for the first-time. In this paper, the performance of experienced learners (i.e. well-trained and familiar with the experimental platforms) was investigated. The paper therefore introduces an empirical multi-group study in order to comparatively evaluate the achievement of learners who used two experimental E-learning environments: avatars as pedagogical agents and game-based E-learning, under two different conditions: novel and experienced.

This study placed a great deal of emphasis on the usability evaluation of multimodal interaction metaphors in knowledge-based environments. It is argued that the usability model consisted of two main components: learnability and Experienced User Performance (EUP) [7]. Learnability refers to a usability component that is measured under the first-time-use condition (i.e. by novel users with limited experience in using the system). The EUP is a usability component that is evaluated under the condition of frequent- or experienced-use. In this paper, the term "experienced" refers to the status in which the user is considered to be well-trained and familiar with the investigated environments. According to this argument, a system could not be judged to be usable until it was tested twice. In the context of E-learning, scholarly research has examined the experimental environments (avatars as pedagogical agents and game-based E-learning) once, which affected the usability conclusions drawn. Therefore, this paper attempts to fill this gap, in the literature, by recognizing and addressing the importance of testing the system twice.

The main goal of this paper is to investigate the differences in learning outcomes of two groups of online learners (novel and experienced) who have used two multimodal experimental environments (avatars as pedagogical agents and game-based E-learning). The remainder of this paper will be organized as follows. Section 2 will describe the reviewed literature as a means of exploring further details on the field and to form a

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theoretical foundation for this paper. The experimental platform was introduced in section 3, including the two experimental interfaces: avatar-based E-learning (ABEL) and game-based E-learning (GBEL). Section 4 presents the experimental design, including the experimental phases and procedures. Section 5 presents the results and findings, including sample characteristics, descriptive statistics and inferential statistics. The discussion and implications were then provided in Section 6, and finally, section 7 provides the conclusion, as a recap of the main points of this study.

II. Literature Review

The rapid growth of the Internet and its applications, educational institutes began using Information and Communication Technologies (ICT) to aid traditional teaching [8]. There is profound evidence of growth in the E-learning market and in the number of E-learning institutes in several regions, such as Asia and Western Europe [9]. When forming an E-learning environment, it is imperative that the learners, technologies, materials and teaching techniques are all taken into consideration [10]. A study by Govindsamy (2001) suggested an instructional development methodology that considers underlying pedagogical principles to be crucial to strengthening E-learning environments [11]. Although, underlying pedagogical principles are naturally multidimensional, their significance to enhancing the quality of E-learning has been well-recognized in the literature [11].

Pedagogically, the purpose of E-learning was to reduce costs, improve the quality of education while also enhancing the learning experience [12]. Although, the primary mode of instruction in many universities is still a lecture format, E-learning aims to change the medium over which the knowledge is transferred [12]. The primary focus of E-learning is to develop course materials in an electronic format. The well-managed formation of E-learning enhances both learning and teaching processes, regardless of the complexity involved [13]. The value of learning online lies in its flexibility that allows the students to learn at a time and place of their choice [14]. However, it is considered to be an independent activity and its progress is influenced by the motivations, perceptions, behaviours and competences of the individuals [15]. As E-learning is seen as a cultural change, change resistance can be resolved by the facilitation of communication, support, constructive feedback and motivation for the online learner [16].

Within the context of E-learning, the learner experience and perception of technology is influenced not only by their gender and their familiarity of the technologies used, but also their learning styles [17]. A learning style refers to the manner by which an individual prefers to acquire knowledge and skills during the learning process [18]. Although most learners possess more than one learning style, they tend to utilize one more than the others. Kolb (1984) organized student learning styles by type, into: divergers, assimilators, convergers, and accommodators [19]. Shaw and Marlow (1999) suggested another classification, based on the learner's strengths and weaknesses, which included: activists, reflectors, theorists and pragmatists [20]. This study investigated the effect of gender and learning style on the students' attitude toward E-learning technologies; interestingly, it found no considerable difference between male and female students [20]. However, the study revealed that the more theoretical the student was, the more negative their attitude would be toward ICT. Another model, by Felder and Silverman (1995), provided more detail on individual learning styles, they suggested four dimensions, based on which learning styles were categorized: information processing (active/ reflective), information perception (sensing/ intuitive), input mode (visual/verbal) and understanding (sequential/ global) [21]. In summary, pedagogical principles, costs and benefits, perceptions of technologies and learning styles should be considered when building E-learning environments.

A. Interactive E-Learning Environments

An interactive E-learning environment refers to a combination of text, graphics, audio, video and other interaction means that are provided to allow online learners to study and interact with greater flexibility and engagement [22]. Combining visual metaphors (text and graphics) with sound (speech and non-speech) and metaphors of an audio-visual nature (avatars with facial expressions and body gestures) are deemed to have a positive influence on the online learner's performance and attitudes. More details about interaction and multimodal metaphors can be found in Alotaibi and Rigas (2010) [23]. Interactive technologies have been found to be useful for E-learning in two major areas: avatars as pedagogical agents and E-learning through edutainment.

B. Avatars as Pedagogical Agents

In recent years, avatars have been utilized as pedagogical agents and virtual instructors to promote the online learner's engagement and to improve learning outcomes. For example, a study by Baylor (2003) evaluated the role of avatars as pedagogical agents in improving the student's learning and motivations, avatars were found to be motivational agents in terms of creating more engagement and in facilitating learning, yet they were less credible in comparison with agents with expertise [24]. Another experimental study by Robertson et al. (2004) examined the effect of animated pedagogical agents on the student's attitudes, they found that this technology promoted the improvement of the student's tendency toward using E-learning interfaces, especially in female students [25]. In addition, an investigation by Dunsworth and Atkinson (2007) examined the effect of avatar-based interactions on student learning, they found that incorporating pedagogical agents with gaze and pointing features could promote learning [26]. Theonas et al. (2008) extended the evaluation of the avatar-based interactions, beyond its general effect on E-learning, in order to explore the effect of several facial expressions on online learners' motivations and learning outcomes. They found that the use of facial expressions had a positive influence on student motivations and learning performance, especially when concerning difficult tasks [27]. In 2009, Alseid and Rigas (2009) investigated user attitudes towards several facial expressions as well as body gestures used by a human-like avatar as a virtual lecturer in online learning. They found that some facial expressions and body gestures were perceived more positively than others [28]. In 2010, the use of avatar-aided E-learning was investigated by Salam and Rigas (2010), in addition to the investigating of the use of text with graphics and video, and they found avatar-aided E-learning to be more efficient [29]. These results support the earlier studies that investigated the significance of virtual learning environments. More recently, Alseid and Rigas (2011) investigated the usability of supplementing speaking avatars with non-speech sounds, such as earcons and auditory icons, to deliver course materials to students [30]. This study revealed that sounds were effective at communicating supportive information as well as being memorable and preferred by users. Another study, by Rigas and Alharbi (2011), investigated the role of multimodal metaphors for increasing the users' engagement and understanding of E-feedback [31]. This study demonstrated that combining multiple multimodal metaphors to communicate information to users does not have any negative effects on the users' ability to understand, when compared with using only visual channels.

C. *E-learning through Edutainment*

The use of electronic games in learning is considered to be useful and natural in knowledge acquisition, because of its role in improving the student's engagement, motivations, performance and attitudes. In fact, an investigation by Sim et al. (2005) into the importance of using humour in educational materials, which is linked to its relationship with usability, found that it is important to consider not only usability factors, but also to incorporate enjoyment elements in the design of learning software for children [32]. This investigation was conducted by observing the behaviour and perception of children (aged 7 to 8 years) while learning and adopting pre- and post-tests to measure learning outcomes. Lin and Gregor (2006) investigated the use of an informal learning environment that included entertaining elements by conducting interviews with educational specialists. They found that there were important characteristics to be considered and guidelines to be followed in order to develop such settings [33]. This study highlighted several motivations of using E-learning systems; some of which are: attractive appearance, interactivity, ease of use and simplicity. The guidelines provided included: the use of interactive multimedia and considerations of self-driven E-learning qualities and the targeted audience [33]. Moreover, another argument suggested that interactive game-based learning could improve the motivations and engagement of online learners, with the consideration of integrating the core virtual reality components: visualizations, modelling and interactions [34].

More recently, an investigation by Kara and Ye ilyurt (2008), into the effect of edutainment and tutorials on the online learner's performance, misconception and attitudes, concluded that edutainment had a positive effect on the student's understanding of the material and attitudes towards the educational software [35]. These results were also supported by another study by Zin and Zain [36]; however, misconceptions were not fully eliminated by using edutainment in E-learning [35]. Currently, E-learning by edutainment has been combined with multimodal interaction approaches, including: speech, sound and avatars. Rigas and Ayad (2010) examined the implications of incorporating edutainment elements in E-learning interfaces and found several enhancements in enjoyment, learning outcomes and attitudes towards E-learning platforms [5]. The experiment relied on avatars with facial expressions and body gestures, as the main modality, they reported an 80% preference rate for the edutainment-enabled environment and a 70% recognition rate for the facial expressions used. This study showed that E-learning should by complemented with not only multimodal metaphors but also amusement features. It put focus on the basic usability attributes of E-learning software, however it lacked the consideration of other E-learning techniques, such as storytelling and virtual classrooms. Another study by Ayad and Rigas (2010) investigated the use edutainment and multimedia elements in E-learning as a means for improving usability of the interface, they found that the treatment improved the effectiveness of the E-learning system and the student's attitudes [4]. One advantage of this study is that it will consider different E-learning approaches by comparing usability aspects of two E-learning platforms: avatars as pedagogical agents and E-learning through edutainment. However, focus was placed on first-time-use only and further considerations of the effect of frequent-use were generally lacking.

III. Experimental Platform

Based on the literature review, an experimental platform was implemented for E-learning with two different interaction approaches: Avatar-Based E-Learning (ABEL) and Game-Based E-Learning (GBEL). The former represented the use of avatars as pedagogical agents and the latter utilized edutainment in E-learning. The E-learning platform was developed specifically for this study in order to present the same learning materials, including explanations and examples of Unified Modelling Language (UML) notations which are commonly used for analyzing and designing systems [37]. There were three lectures of increasing complexity, they were presented by either avatar-based interactions or through edutainment techniques. The lectures (and their learning materials were adapted from Lethbridge et al., 2005 [37]), contained the most frequently used UML notations, such as classes, methods, attributes, multiplicity and associations. The more complex the task, the more notations and advanced UML techniques were involved. The first lecture presented the class diagram for the elevator control system which was considered to be relatively simple. The second lecture presented the class diagram of a document composition system which was regarded to be moderately complex. The third lecture illustrates the class diagram for a complex banking system, this presentation was deemed to be difficult in comparison to the two previous lectures. The three levels of lecture complexity were separated by several factors. Some of which concerned: the number of classes, the number of associations and multiplicities, and the type of associations involved. The three class diagrams of elevator control system, document composition system and banking system were presented in lectures one, two and three respectively.

A. Avatar-Based E-Learning (ABEL)

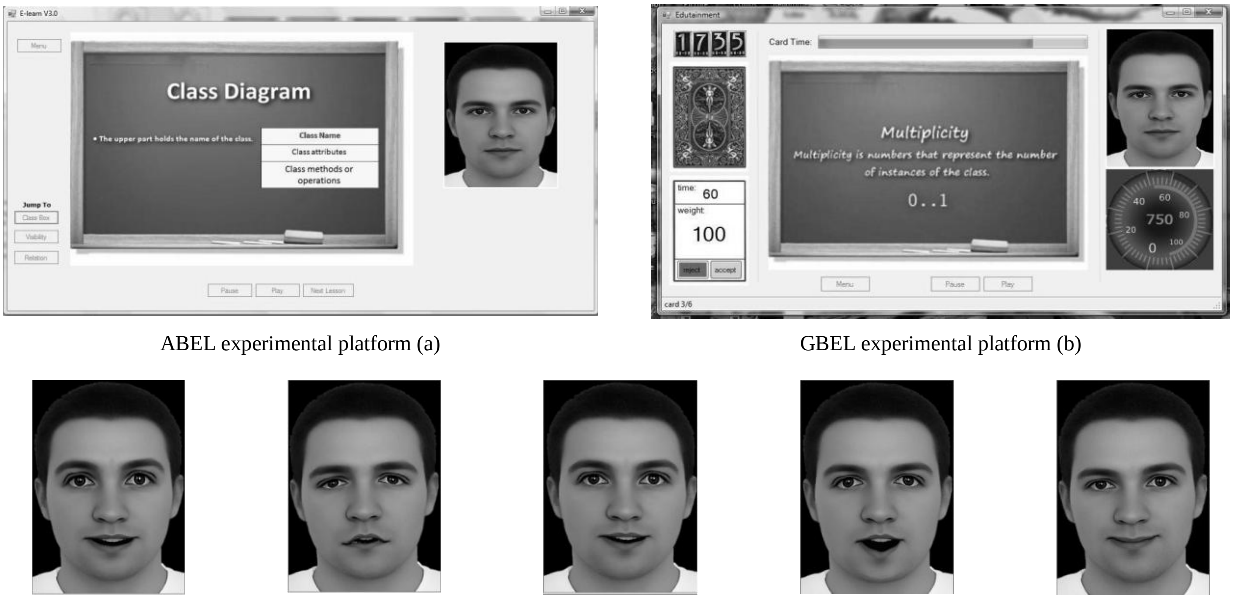
The ABEL experimental platform was developed specifically to serve this empirical investigation. The platform presented the learning materials (lectures one, two, and three) using avatars as pedagogical agents. It was built over an existing visual-only E-learning interface, but with supplementary multimodal metaphors to enforce the information being communicated. Different guidelines for interface design were followed during the implementation of the ABEL platform, such as guidelines for multimodal information communication [38] and guidelines for multimodal design of user interfaces [39]. For example, when the user would move the mouse over the diagram, associations were presented by natural recorded speech sounds, while non-speech sounds were employed to communicate multiplicity. Both speech and non-speech metaphors were utilized to supplement the visual presentation of the class diagram. Simultaneously, a pedagogical agent introduced the classes with further elaborations on the class attributes and operations using special effects. The user could choose to pause or replay the agent presentation at anytime, with the feature of having other metaphors not being intercepted.

The implementation of multimodal interaction involved the association between information being communicated and metaphors being used, including non-speech, speech, and avatars. In non-speech metaphors, earcons were mapped to multiplicity, due to its well-recognized role to communicate a narrow range of values, like numbers. A set of six groups of musical notes were designed based on empirically derived guidelines [40] to communicate six multiplicity types. Earcons were composed of two parts which were separated by a silence period of 0.6 seconds. In each part, timbre and rhythm were utilized to differentiate the six musical note groups; the timbres used were piano and seashore and the rhythms used were single note, serial notes and rising pitch notes. Each note started from the middle C in the chromatic scale. In the speech metaphors, natural recorded speech was utilized to communicate associations among classes, because this is known to improve the comprehension of online learners [41]. In avatar-based interactions, speech was combined with facial expressions. It was important to synchronize the spoken text with the body movements and facial animations of the character, this relied upon a 3D humanoid model which was the virtual lecturer. The learning materials were presented by avatar-interaction using spoken lectures with facial expressions. In the spoken lecture, the pedagogical agent introduced lessons based on verbal and non-verbal communications. Based on empirical facial expression results of E-learning interfaces [42], a combination of: interested, happy, sad, smiling and amazed were utilized to facilitate non-verbal communication by the avatar, as shown in Fig. 1 (e), (f) and (g). Fig. 1 (a) shows the ABEL platform.

B. Game-Based E-Learning (GBEL)

The GBEL environment was also built for the experimentation purposes. The learning materials were similar to that in the ABEL platform, but it was presented as three games of increasing complexity: elevator control game, document composition game and bank game. Each game involved one to three levels respectively, which determined its complexity. The elevator control game (easy) involved just one level, whereas the document composition game (moderate) had two levels and the bank game was designed to be complex, as it involved three levels. The learning materials were introduced by talking avatars with facial expressions and body gestures which were aided by animated UML notations and visual special effects were used to draw a certain portion of the class diagram. The environment facilitated feedback to the user which was of a fun and engaging nature, this was presented by another humorous and entertaining avatar [43]. The humorous avatar relied on positive and negative feedback messages (provided by speech, auditory icons and facial expressions) to indicate whether the user's actions were right or wrong, respectively. For example, a correct answer, by the user, would receive a positive feedback message which simultaneously showed a happy face while also playing an applause sound. Similarly, an example of negative feedback involved the showing of a sad face simultaneously with the sound of booing being played. In addition, the experimental environment was created as a multi-level game in which the transition from one level to another was made by comparing the accumulated points with an empirical threshold used specifically for this study.

Fig. 1 (b) shows the GBEL platform. The game screen was divided into hints cards (left-side), presentation area (middle), avatar (upper-right) and my score (lower-right). In the upper-left-side of the game screen, when the user double-clicked on the hints card (face-down), the card would be flipped face-up and drawn underneath its original place. The virtual lecturer (upper-right) would start to introduce the hints verbally and nonverbally. In the diagram area, the animated UML notations were illustratively synchronized with the avatar's speech by moving classes, linking classes by associations and assigning multiplicities to associations. Upon the completion of the hint, the user was required to accept or reject the hint within a timeframe in order to score the points associated with that hint, as shown in the face-up card (lower-left). The card itself was divided into four areas: time, weight, and acceptance and rejection buttons. If the user didn't respond within the timeframe given to the hint, or if they rejected a correct hint or accepted a



ABEL experimental platform (a) GBEL experimental platform (b)

Happy (c) Sad (d) Interested (e) Amazed (f) Smiling (g)

Figure 1. ABEL (a) and GBEL (b) experimental platforms and facial expressions used (c) (d) (e) (f) (g)

wrong hint, then negative humorous feedback would be given by the feedback avatar and the card weight would then be subtracted from the accumulated score shown in the my score area. Otherwise, humorous positive feedback would be presented and the card weight then added to the overall score. Above the card area, the highest score of all players was also shown and compared with the current player's accumulated points in order to create a sense of competition between the users [43].

IV. Experimental Design

This study consisted of two experimental phases: learnability and EUP. The experiments involved 148 participants, they were organized equally into two groups: ABEL and GBEL. The two groups took part in the learnability and EUP experiments with different experience levels. The experimental platforms and achievement tests were reviewed and validated by a panel of experts.

A. Experimental Phase One (learnability)

The main purpose of this experiment was to evaluate the learnability of the two experimental platforms: ABEL and GBEL. The experiment measured student achievements under the first-time-use condition, this reflected the first component of the usability model [44]. The experiment relied on a "between-participants" design [45], which allows different groups of users (independent groups) to interact with different systems in order to control the learning effect. Two groups were recruited to empirically evaluate the two experimental environments. Each group was assigned to an experimental platform for testing. In addition, each group consisted of 74 inexperienced users, who only had the chance to interact with the experimental platform during the experiment.

B. Experimental Phase Two (EUP)

The first experimental phase aimed to measure the performance of inexperienced users who interacted with the experimental platform for the first-time. The aim of the second experiment was to investigate the effect of the experience and familiarity of the system on the user's performance. In order to address this aim, the participants were provided with multiple training sessions, until they demonstrated that they were experienced with the experimental platform. The term experienced in this experiment refers to the status in which the user was regarded as well-trained and very familiar with the experimental system. The sample size and measures were similar to those in the first experimental phase in order to facilitate comparison (148 experienced users). In order to investigate the effect of increasing experience or familiarity with the systems, it was important to measure the participants' achievements twice, based on the "within-participants" experimental design, this would control the effect of other external factors [45]. However, the comparison between the two interface conditions (ABEL and GBEL) is still similar to the first experiment which was based on a "between-participants" experimental design [45].

C. Experimental Procedure

In the two experimental phases, the same procedure was follow to maintain consistency throughout the experimental programme. The experiment commenced with the answering of pre-experimental questions, into the participant's age and education, through the use of a research instrument (i.e. questionnaire). In addition, the user was asked to specify their prior knowledge of computing, the Internet, E-learning, object-oriented paradigms and class diagram notations. Afterward, the users performed common tasks in which the order of educational material presentation was counterbalanced to eliminate any possible learning effects. Finally, the user was instructed to answer the post-experimental questions which evaluated the participants' knowledge through the use of achievement tests.

D. Common Tasks

Each user was instructed to complete six common tasks of increasing complexity: easy, moderate and difficult. The task was presented, as a general statement, followed by several instructions. The instructions guided the user to utilize the provided features, such as moving the mouse cursor over a certain UML notation to receive information presented (e.g. class name, multiplicities) by the two multimodal interface techniques. The task was accomplished once the task instructions were followed and once several questions were answered for: memory recall and recognition. The questions measured the student's learning outcomes. In recall questions, the user's ability to recall communicated information was evaluated. In recognition questions, the user was provided with a set of alternative answers and they were required to recognize the correct one.

E. Variables

The independent variables were the factors manipulated in order to evaluate their effect on the obtained result; these were as follows:

- Multimodal interface technique: this study investigated the effect of two multimodal interface techniques in E-learning: ABEL and GBEL.
- Familiarity with the system: the effect of familiarity or experience with the multimodal interface techniques were evaluated by two samples: inexperienced and experienced users.
- Complexity level: the effect of such interface techniques were related to the task's complexity, this included three levels: easy, moderate and difficult.
- Evaluation questions: the investigation also considered the type of evaluation questions needed, which included recall and recognition questions.

The dependent variables presented the measured effect (measures) which resulted from the manipulation of the independent variables; these included:

- Achievement tests: this variable was measured by calculating the number of questions correctly answered within the time threshold, as well as the number of allowed attempts. It is noteworthy that partially correct answers were accepted in the recall questions, whereas only the correct answers were considered in the recognition questions.

V. Results

The analysis of the results will be organized into the following three sections: sample characteristics, descriptive statistics and inferential statistics [46]. Sample characteristics showed the participants demographics, including: age, education, Internet experience, computing experience, E-learning experience and background knowledge about the subject (UML and class diagrams). The descriptive statistics illustrated the mean values of the achievement scores for participants in the two experiments which used the two experimental platforms. The inferential statistics examined the statistical significance with regards to the differences between the groups, this was done through the use of two types of t-test: independent and paired t-tests.

A. Sample Characteristics

Data was gathered from the achievement tests performed by the participants. The sample size reached an acceptable level, as 148 responses (n=148) were collected and considered for analysis. The general demographics of the participants are shown in Table 1. Interestingly, participants came from computing and informatics backgrounds. It can be seen from the table

TABLE I.
SAMPLE CHARACTERISTICS

Participant's demographics		Number	Percent	Mean
Number of participants		148	100	-
Age		-	-	23.7
Education level	Masters	48	32.4	-
	Bachelor	87	58.8	-
	Two year diploma	13	8.8	-
Internet experience	Uses Internet more than 10 hours a week	127	85.8	-
	Uses Internet less than 10 hours week	21	14.2	-
Computing experience	Uses computers more than 10 hours week	131	88.5	-
	Use computers less than 10 hours a week	17	11.5	-
E-learning experience	Had experience with E-learning	66	44.6	-
	Had experience with E-learning	82	55.4	-
Background knowledge about the subject (UML and class diagrams)	Had excellent knowledge about the subject	24	16.2	-
	Had good knowledge about the subject	82	55.4	-
	Had limited knowledge about the subject	34	23.0	-
	Had no knowledge about the subject	8	5.4	-

that the mean value of age was approximately 24 years. In terms of education level, 48 (32.4%) participants held a master degree, 87 (58.8%) had a bachelor degree and 13 (8.8%) had a two year diploma. In addition, the participants indicated that they had excellent Internet experience, with 127 (85.8%) using the Internet more than 10 hours a week. Similarly, the participants were generally experienced in their use of computers, with 131 (88.5%) using computers for more than 10 hours a week. With regards to E-learning experience, 66 (44.6%) participants had prior experience of E-learning systems, whereas 82 (55.4%) had no experience. Furthermore, the participants' background knowledge about the subject matter (UML and class diagrams), ranged from excellent to no experience, with 24 (16.2%) having excellent knowledge about the subject; 82 (55.4%) having good background; 34 (23%) had limited knowledge and 8 (5.4%) had no knowledge about UML or class diagrams.

B. Descriptive Statistics

In Fig. 2, the mean values for the learning outcomes are shown in accordance to the overall achievement score, recall achievement score and recognition achievement score in the learnability and EUP experiments for ABEL (a) and GBEL (b). At a glance, it can be seen that the learning outcomes increased with the increasing experience of online learners for both ABEL and GBEL. In Fig. 2 (a), the overall achievement score for first-time-use of ABEL was 16% lower than that for frequent-use. The difference in recall achievement scores maintained relatively the same level for overall scores, with a 17% variance in favour of EUP. In addition, the recognition achievement, using ABEL, witnessed a lower difference with only 12% improvement in favour of EUP. In Fig. 2 (b), the mean value of the overall achievement score for first-time-use of GBEL was found to be 13% lower than that for frequent GBEL use. The difference in achievement scores, between first-time-use of GBEL and frequent-use for recall and recognition questions showed a similar picture. In summary, a range of 12% to 17% improvement in ABEL users' performance resulted from increased user experience, compared with 12% to 14% for GBEL.

Fig. 3 shows the mean values of the learning outcomes, according to easy, moderate and difficult learning tasks performed for the learnability and EUP experiments using ABEL (a) and GBEL (b). Overall, it can be seen that the improvement in achievement results, resulting from increased user experience, increased as the task complexity did for both ABEL and GBEL usage. In Fig. 3 (a), there was a 10% improvement in learning outcomes resulting from frequent-use of ABEL in easy learning tasks, compared with first-time-use. The improvement steadily increased to 15% in moderate tasks and 17% in difficult tasks. In Fig. 3 (b), the learning outcomes for easy tasks, using GBEL, witnessed just a 6% difference

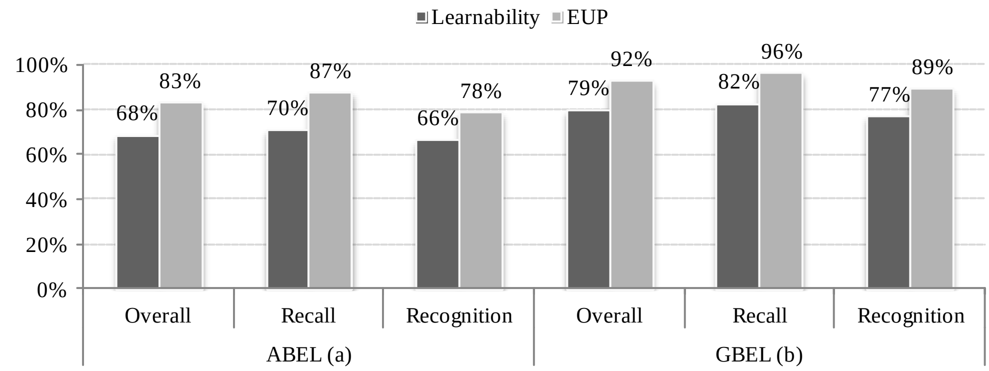


Figure 2. Mean values of learning outcomes, according to: overall achievement score, recall achievement score and recognition achievement score in the learnability and EUP experiments for ABEL (a) and GBEL (b).

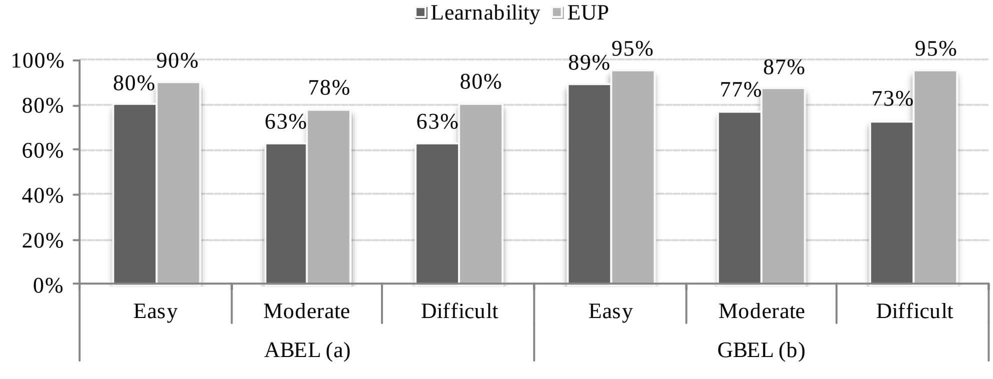


Figure 3. Mean values of learning outcomes, according to: easy, moderate and difficult learning tasks performed for the learnability and EUP experiments using ABEL (a) and GBEL (b)

between learnability and EUP experiments. The difference showed a steady increase to 10% for moderate tasks and 12% for difficult tasks. In summary, it can be said that the more difficult the tasks, the more significant the effect of user experience on performance, particularly when using ABEL.

C. Inferential Statistics

Inferential statistics were utilized to examine any significance between the two groups: ABEL and GBEL, as well as the two experiments: learnability and EUP. Since the achievement score was a parametric variable, an independent t-test was utilized to examine the significance between the means of the independent groups within each experiment, due the between-participants experimental design [46]. The paired t-test (i.e. related t-test) was utilized to examine the significance between the two experiments, due to the within-participants' experimental design [46], in which the same participants performed the tasks under two conditions: first-time and frequent-use. Table 2 shows the results for the independent t-test for the within-experiment group comparisons, and Table 3 shows the paired t-test results for the cross-experiment group comparisons. All of the results were shown to be statistically significant.

VI. Discussion

Game development is one of the most interesting topics in E-learning in terms of edutainment. Edutainment systems enhance the students' ability to learn, due to the high emotional involvement they offer. In addition, the reception of learning materials through multiple sensory channels (multimodal) can increase the learning outcomes and the ability to recall. The combination of edutainment and multimodal interaction has previously been shown to be usable in E-learning environments. In this investigation, a steady increase in the learning outcome was noted which resulted from increasing experience or familiarity with multimodal metaphors in edutainment. This could be attributed to the fact that the effectiveness of interaction metaphors and edutainment elements can increase when a student becomes more familiar with them.

TABLE II.
INDEPENDENT T-TEST RESULTS FOR WITHIN-EXPERIMENT GROUP COMPARISONS

Experiment	Variable	Category	Conditions	t-test results	Significant	
					Yes	No
Learnability	Achievement test	Overall	GBEL vs. ABEL	t_{146}=6.172 , p<0.001	√	
	Question type	Recall	GBEL vs. ABEL	t_{146}= 4.308, p<0.001	√	
		Recognition	GBEL vs. ABEL	t_{146}= 4.083 , p<0.001	√	
	Complexity level	Easy	GBEL vs. ABEL	t_{146}=3.416 , p<0.005	√	
		Moderate	GBEL vs. ABEL	t_{146}=4.689 , p<0.001	√	
		Difficult	GBEL vs. ABEL	t_{146}=2.883, p<0.01	√	
EUP	Achievement test	Overall	ABEL vs. GBEL	t_{146}=6.998 , p<0.001	√	
	Question type	Recall	ABEL vs. GBEL	t_{146}=4.893 , p<0.001	√	
		Recognition	ABEL vs. GBEL	t_{146}=4.410, p<0.001	√	
	Complexity level	Easy	ABEL vs. GBEL	t_{146}=2.579 , p<0.05	√	
		Moderate	ABEL vs. GBEL	t_{146}=3.534 , p<0.005	√	
		Difficult	ABEL vs. GBEL	t_{146}=5.785, p<0.001	√	

Notes: df = 146, t-test critical vale (cv) = 1.960 (at 0.05 significance level)

TABLE III.
PAIRED T-TEST RESULTS FOR CROSS-EXPERIMENT GROUP COMPARISONS

Approach	Variable	Category	Conditions	t-test results	Significant	
					Yes	No
ABEL	Achievement test	Overall	EUP vs. Learnability	t_{73}=9.079, p<0.001	√	
	Question type	Recall	EUP vs. Learnability	t_{73}=6.485, p<0.001	√	
		Recognition	EUP vs. Learnability	t_{73}=4.523, p<0.001	√	
	Complexity level	Easy	EUP vs. Learnability	t_{73}=3.794, p<0.001	√	
		Moderate	EUP vs. Learnability	t_{73}=5.693, p<0.001	√	
		Difficult	EUP vs. Learnability	t_{73}=4.996, p<0.001	√	
GBEL	Achievement test	Overall	EUP vs. Learnability	t_{73}=9.295, p<0.001	√	
	Question type	Recall	EUP vs. Learnability	t_{73}=6.690, p<0.001	√	
		Recognition	EUP vs. Learnability	t_{73}=5.515, p<0.001	√	
	Complexity level	Easy	EUP vs. Learnability	t_{73}=2.840, p<0.01	√	
		Moderate	EUP vs. Learnability	t_{73}=3.789, p<0.001	√	
		Difficult	EUP vs. Learnability	t_{73}=8.672, p<0.001	√	

Notes: df = 146, t-test critical vale (cv) = 1.960 (at 0.05 significance level)

This investigation has revealed that multimodal metaphors in edutainment environments are effective in E-learning. In particular, with increasing user experience, the incorporating of multimodal metaphors in edutainment interfaces could significantly enhance the learning outcomes and usability of E-learning systems. Thus, multimodal edutainment resulted in an increasing levels of enthusiasm, enjoyment and satisfaction during the repeated interaction, this can be linked directly to the ability of participants to accomplish learning tasks effectively. Regarding the recall and recognition ability of participants, evidence from this experiment suggested that multimodal metaphors can contribute significantly toward memory recall activities, particularly with repeated interactions and increasing user experiences. The ability to recall was higher for the edutainment platform, especially with experienced user performance. In comparison with the recall ability, the recognition ability was between 3% and 7% lower. However, the recognition abilities, resulting from incorporating multimodal metaphors and edutainment elements into the E-learning interface, were significantly higher than for those using avatars as pedagogical agents. With regard to task complexity levels, there was a steady increase in the effect of increased experience on learning outcomes in both platforms. In addition, the incorporation of edutainment elements clearly have a considerable effect on user performance across different complexity levels, particularly for frequent-use conditions. In summary, the effectiveness of multimodal metaphors for edutainment was successfully proven, particularly with increasing user experience, memory recall activities and difficult learning tasks.

Several limitations were encountered which related to the participants ability to recall in ABEL, and efficiency concerns were also noted. During the experiment, the improvement in recall achievements caused by increasing experience was higher in ABEL than in GBEL. This can be attributed to the boredom and frustration experienced by ABEL users, especially in difficult tasks. It was also noticed that the role of users was different in both platforms, since the ABEL users ideally received knowledge and the GBEL users were more engaged in game activities. The volume of interaction was higher in GBEL, which increased knowledge and enjoyment. However, the time to accomplish tasks and error occurrence were also increased which undermined the efficiency of the GBEL platform. Therefore, it can be said that the effectiveness of the multimodal edutainment techniques in E-learning are coupled with efficiency concerns. In summary, this experimental study proposes several suggestions for tackling the highlighted concerns and limitations.

This study is of great importance to practitioners and researchers as it examined the usability of emerging techniques in E-learning, while also highlighting new directions for further research. It is important that E-learning interface designers embrace the development of multimodal interaction in edutainment environments. As such, facial modalities, alongside speech and earcons in E-learning interfaces, need to be encouraged and incorporated in an enjoyable and entertaining way.

It is also important to be aware of potential improvements, due to the effect of increasing experience and repeated interaction in improving the usability of such techniques, compared with initial interactions and first-time-use. This study has provided further direction for research, as such investigations into different game designs and the use of personalized interaction in edutainment are needed. In the current literature, several studies investigated the usability of edutainment elements, in comparison with non-edutainment interfaces. However, a comparison of different edutainment techniques and game designs would merit further investigation. In addition, supplementing edutainment elements with personalized interactions and tailored interfaces could potentially increase the usability of E-learning systems further. This study could also be expanded for children, in order to investigate the effect of multimodal edutainment techniques on learning outcomes in younger learners (such as primary school students). It can be said that various edutainment elements were initially investigated and herein proven successful; therefore, new directions for further research should include different game designs and personalization techniques.

VII. Conclusion

A two-phase experimental research project has herein been reported, focusing on the effect of multimodal interaction in edutainment environments and the effect of increasing user experience. Two experimental platforms were designed especially for this study, the first relied on avatars as pedagogical agents and the second used edutainment for E-learning. These two platforms were empirically examined, twice, for learnability and EUP experiments. The two experiments were carried out by 148 participants, they performed three tasks of increasing complexity and then answered recall and recognition questions. The results suggested that the inclusion of multimodal metaphors in edutainment environments greatly influenced the participants' learning outcomes, particularly with increasing user performance. In addition, the effect of experience was found to steadily increase with the increasing complexity of learning tasks for both platforms. It was also found that increasing user experience had a remarkable effect on the memory recall activities and recognition abilities across both platforms. The inferential statistics also indicated that these results were statistically significant.

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