An Evaluation of the Efficacy of a Perceptually Controlled Immersive Environment for Learning Acupuncture

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An Evaluation of the Efficacy of a Perceptually Controlled Immersive Environment for Learning Acupuncture

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***Abstract*— This paper presents a basic but functional Perceptual User Interface (PUI) controlled immersive environment (IE) on an electronic learning platform (e-Learning) in order to deliver educational material relating to the NADA (National Acupuncture Detoxification Association) protocol for acupuncture. The purpose of this study is set out a proposed process for evaluating the learning efficacy of the PUI IE e-Learning application when compared with a typical Graphical User Interface (GUI) e-Learning IE application. Both are to be compared to a more traditional learning method. This paper evaluates user interface (UI) sentiment of the systems in advance of this proposed evaluation.**

Keywords—Acupuncture; National Acupuncture Detoxification Association; NADA protocol; Perceptual User Interface; Graphical User Interface; Electronic Learning; Immersive Environment;

I. INTRODUCTION (*IMMERSIVE ENVIRONMENTS*)

The use of immersive environments, or IE, by the general public is on the increase. This is due in part to the development of faster and cheaper mobile processors, the maturity of a middleware market in games engine development software, a new prosumer sensor market, and the public acceptance of mobile processing devices such as tablets and smartphones.

The growth in public use of IEs is historically driven by the gaming market. Video gaming once occupied a niche area, but this has now expanded to the wider public with the help of a significant smartphone and tablet user base and wireless broadband delivery system. Now that game delivery on a large scale is normal on these devices, the use of gamified elements and game-like immersive environments is beginning to expand into non-game uses such as social media, electronic learning (or e-Learning) , and mobile learning (or m-Learning) [1].

For the purpose of this paper, we will use the accepted definition of e-Learning as using a desktop PC as an educational software platform rather than tablet or mobile devices, which would fall under the term m-Learning (or mobile learning).

The appetite for adoption of IE in e-Learning is happening despite the lack of a coordinated body of evidence showing genuine benefit in educational efficacy [4].

With this in mind, it is best to begin to evaluate our interactions with IE in order to quantify benefits and enact a framework for more efficient development and iteration of favorable systems.

IEs also require novel user interfaces above the desktop paradigm and graphical user interface, or GUI [5-9]. The complexity of choice in navigating and interacting within a 2D or 3D immersive environment demands a well-chosen range of inputs matched to tasks. Traditionally, gaming used GUI controls such as the keyboard and mouse, or modified versions of these as seen in the gamepad or joystick. The controls were used both for navigation of and interaction with a 2D or 3D IE.

The GUI game control paradigm has reached a satisfying level of both complexity and intuitiveness in relation to various genres such as interaction with a first person shooter, or FPS environment [13].

Moving on to new platforms such as mobile and tablet, the controls offered by touch screens give an intuitive and low cognitive impact abstraction of control, especially when combined with the accelerometers and voice control present in most devices [6]. Touch based control has already gained wide acceptance, and these is some scope for mapping these controls to an IE, though this takes more planning, development, and user training.

Therefore, in order to address the complexity of an IE, an advance on typical GUI/desktop paradigm control systems is required. However, a more complex 3D input device is not an ideal option for mass market consumption or e-Learning. This is due in part to the lack of homogeneity, cost, increased cognitive load, and motor complexity or tiring [5-9]. For wider acceptance, it must be able to reach out to the user with a low barrier of entry, much as touch control has done.

Perceptual user interfaces, or PUI [6], can offer a solution and benefit in two ways. Perceptual sensors offer a low barrier entry for users, important when dealing with the general public. Also, they offer a wide range of possible controls to match the complexity of IE navigation and control.

Typical perceptual user interfaces include computer vision for tracking and motion capture, voice control, and expression recognition. All of these are seen in the Kinect, who publish UI guidelines based on their experience and feedback [14].

The approach of using combined sensors or inputs is termed multimodal, and benefits us by allowing us to select a range of low cognitive impact controls for effective task/control mapping [5-9].

Such benefits of a PUI usually can only be seen fully in hindsight, such as the benefits of the Mouse and desktop paradigms for the GUI of PCs that we have used productively for over 40 years.

Therefore, while it is early days for perceptual controls, it would benefit academics and consumers to start to quantify benefits of various PUI elements so they can be developed, combined, and iterated quickly and successfully [2, 22].

This paper explores the benefits of expanding on that framework by starting to create a process for comparing advantages or disadvantages of one type of PUI IE e-Learning over GUI IE e-Learning. In order to do this we have developed an application called Virtual Acupuncture. We will also include the evaluation of more traditional education techniques in this framework comparison.

II. E-Learning and M-Learning Apps

We present a simple electronic IE system as a proof of concept for enhanced teaching and learning of the NADA Protocol in acupuncture.

Any advantages in using an immersive environment for training are not conclusively proven [2, 3]. This may in part be due to the variety and newness, even rawness, of the IE training and teaching/learning systems. An immersive environment may offer some motivation to engage in and complete training. Likewise, it could prove off putting or insurmountable to others. Any UI sentiment should be captured in pre- and post-questionnaires.

Some advantages of IEs may be increased motivation or engagement or even increased efficacy of learning due to triggering ideomotor or common coding responses [17]. Depending on the results of this paper, there may be further reason to pursue this avenue.

If IE are to be used, one maxim that would appear to be true is that IEs, though complex in possibility, should have a clear and untiring control system [5-9, 14].

There exist m-Learning versions of acupuncture apps, but all are of a limited interaction in comparison to our developed application.

The ones found and listed later in the paper offer either straightforward identification of acupuncture points from images, which is of the variety seen in textbooks, or a 3d navigable model of human body or parts on which points or meridians are displayed.

No apps apart from AcuMap Ear [20] offer selectable points in order to display labels, or a sandbox/practice mode where selecting a part on the body will reveal either a point with label or a null result. AcuMap Ear, while having point selection capabilities and 2D interaction, does not combine this with a 3D IE.

Additionally, this functionality in our application is combined with a quiz mode that offers randomized and timed questions. The user responds to a point description by selecting the body area presumed to be correct. The user is given positive or negative feedback on his choice, and the quiz proceeds accordingly if correct, or continues to offer the question until a 20 second countdown finishes.

III. Background of Problem

The University of Westminster is committed to m-Learning and e-Learning. At the beginning of 2015, the University pioneered the largest rollout of iPads to students in the UK, with nearly 900 going to level 5 and 6 students in the faculty of science and technology department. This academic year 2016/7, all level 4 students will receive them as well, to a total homogenous digital device user base of over 1000 iPads.

The department includes courses in Biomedical Sciences, Computer Science, Psychology, Engineering, and Life Sciences. As part of this launch, faculty are committed to engage students in mobile learning concepts using iPads, other mobile devices, or desktop PCs and Macs via web browser or native applications. These concepts include digital extensions of traditional pedagogy such as flipped classrooms, blended learning, student-led learning, and self and peer assessment.

Advantages of these pedagogic processes are understood to be rooted in the deep learning and constructivist theory of teaching by Biggs [18] that ties assessment to learning outcomes.

While there are some studies being done by University of Westminster researchers on these concepts and the uses of e-Learning and m-Learning to facilitate them, the advantages and potential drawbacks are still not fully researched or quantified. Partly this is due to the novelty of the systems to the teaching environment, and in part due to the complexity of arrangements that can be made for teaching with various hardware, software and platform systems.There is a start in comparing traditional methods to e-Learning and m-Learning simultaneously [2-4], so the field is beginning to be evaluated quantitatively.

However, IEs and PUIs for any such systems add further layers of complexity to be evaluated. As put forth by Turk [6], these perceptual inputs are valuable to the developing IEs where traditional GUI is inadequate. Even so, with PUI, there are usability issues from the start.

As part of our ongoing research, the Serious Games Group at Westminster is committed to developing a framework for comparison of PUI in the use of immersive environments. A basic framework was laid out in a previous paper for the Immersive Technologies for the Effective Learning Workshop in the IMCL 2015 Conference and expanded to a journal article for the International Journal of Interactive Mobile Technologies [22]. This paper is part of the work towards that framework, and here we begin to create the framework to test PUI IE e-Learning against GUI IE e-Learning and also traditional baselines in learning efficacy and UI sentiment. We intend to start to capture any strong usability issues alongside UI efficiency evaluation. In this paper we will present a UI Sentiment Evaluationon the PUI IE e-Learning Acupuncture application.

IV. IMMERSIVE ACUPUNCTURE

The use of a PUI and IE in this application is intended to begin to replicate a digital version of a real world situation. The leap motion captures finger and hand movement in a small space, and the use of this as the PUI offers a fair approximation of the physical interaction required for needle placement in a physical subject.

One enduring issue with computer simulations of medical procedures is the level of accuracy necessary for effective teaching. It was found in early medical surgery simulations that the representation of items and procedures was inadequate to convey the necessary concepts with accuracy, and could even damage teaching. There is also an issue with sensor accuracy with interaction.

The implications of the interaction interface and accuracy were discussed with Lee Butler of the Acupuncture and Chinese Medicine Course at the University of Westminster, and it was determined that rather than have inaccurate needle locations, a more general finger point was an appropriate parallel precision for general teaching of a set of protocol points.

This immersive learning environment is not gamified to a degree that could be studied or measured by Octalysis [28], and perhaps this is a way forward in development. However, it has some basic elements that mark it as a functioning e-Learning application in an IE accessed with a PUI. As such, we will set out a framework to test its efficacy in enhancing learning of the NADA Protocol for acupuncture.

The software provides a practice/sandbox mode for learning by revealing the labels on hint nodes when tapped with a finger. This consists of a series of unnamed nodes populating typical needle locations for treatment. The user selects each node with a finger gesture, and the treatment associated with the node is displayed.

With this, we can set a framework that reviews users who complete the training period with hint nodes under PUI, e and m-learning, and compare their post training test results to that of the control group that have studied a typical presentation of the labelled nodes.

There exist applications for acupuncture learning and reference, such as Easy Acupunture 3D, [15], Ear acupuncture by Marco Kersting [16], and Acumapa, an acupuncture AR overlay [17] These offer a variety of interactions, mostly of the variety that offers a 2D image or 3D model to navigate with displayed reference of point names and effects.

An application that offers an acupuncture quiz based on a presented image is Opentcm [27]. However, this is not interactive in the way that our training mode is, where users can select any area on the 3D body part and get immediate feedback on failure to find a point, or confirmation on point found and its effect.

Our software offers a new feature above this small collection of acupuncture applications. We present an interactive quiz within an immersive environment. Unlike other apps or quizzes, the user can navigate the immersive environment and select areas they believe to have points.

In the case of our PUI IE e-Learning version, they do so via finger taps in mid-air. In our proposed GUI IE e-learning version, the area on the screen is selected via mouse-click.

The feature unique to our application is the live interaction element: In both cases there is live negative feedback of a null or incorrect point selection, and live positive feedback of a correct point selection.

V. NADA PROTOCOL AND EAR SCENARIO

As a contained test case, the NADA protocol (National Acupuncture Detoxification Association) was suggested by University of Westminster lecturer Lee Butler. This approach focusses on the patient's ear and its points which are alleged to affect a wide variety of body organs. In the case of the NADA protocol, the organs are targeted with the intention of detoxification and treating addictions, among other targets such as behavioral health and trauma.

Under the protocol, up to 5 needles are applied to a range of points in the ear for 30-45 minutes, and have reported behavioral benefits for the patient. The choice of this approach is due to the contained nature of the body part and treatment approach.

The typical ear points for the NADA protocol are the Sympathetic, Shen Men, Kidney, Liver, and Lung. Other points we will also cover for the overall ear scenario are the Heart, Allergy, Shoulder, Blood Pressure, Hormone, Histamine, and Eye.

Figure 1. Sandbox Development screenshot for Ear NADA Protocol *(http://acu-detoxtrainingworkshops.co.uk/nada-5-point-protocol.html)*

The learning objectives of the training application in the first instance are simple; the student is to be familiarized with the locations of the NADA protocol points, along with the other major points in the ear.

VI. STATEMENT OF PROBLEM

In this paper, we begin to create a test framework for PUI IE e-learning against GUI IE e-learning and Traditional teaching for learning efficacy and UI sentiment. We intend to start to capture any strong usability issues alongside UI efficiency evaluationm, with UI sentiment captured as a first step.

With this proposed framework we hope to provide guidance for making more informed decisions around e-Learning initiatives, to begin to provide some quantification of any benefit of e-learning, and to make progress in development and rapid iteration of effective and non-tiring PUI [14] for IE.

As Bowie State University highlighted in their study, there is a need for more material to support use of m and e-learning [2]. One advance we have above other e-Learning studies is the addition of an IE. Additionally, we can control the IE with a PUI. In this way we hope to evaluate any significant differences in learning efficacy between PUI IE e-Learning, GUI IE e-Learning and traditional methods. UI sentiment was captured for the systems as a first step for this paper.

VII. Hypothesis

For our final proposed framework, statistical tests with the framework are to be performed using SPSS. Initially, each system will be subject to a paired samples t-test that is evaluated for significant gains in learning.
These results will then be used in a one-way between-groups analysis of variance (ANOVA) to determine any statistically significant difference in the mean changes in score of the three study groups: PUI IE e-Learning, GUI IE e-Learning and traditional for the Virtual Acupuncture application.

The following hypothesis will be tested:

***H_0:** There is no difference in learning efficacy among the PUI e-learning, e-learning, and traditional methods of acupuncture teaching*
***H_1:** The learning efficacy of at least one method differs significantly.*

VIII. Methodology

This study is to assess 2 digital platforms for an acupuncture teaching application. These are to be compared against a group that presented the material in a traditional teaching manner.

Since the testing will require that subjects for each system are naïve, the study is to be a between-subjects design with multiple groups. Each subject group is to be presented with a pre-questionnaire that captures the demographic, level of knowledge of the subject, and level of experience and preference of mobile, e-learning, and PUI/immersive environment devices. Age and diversity of background and training were also to be captured for later correlation study.

Subject groups are to be tested before and after the training. These pre- and post-tests are a quiz of 5 questions with 20 seconds per question. The questions covered the NADA protocol material presented by the learning systems, and were different for pre- and post-tests.

The mean and standard deviation of the change in learning results are to be compared via a series of paired samples t-tests for any significant change at the 0.05 confidence level. These results are then subject to a one-way between-groups ANOVA analysis of variance.

The post-questionnaire captured perceptions of learning and system efficacy and PUI /UI sentiment. Correlations between UI sentiment and pre-questionnaire information may be pursued.

The overall view of the experiment is as follows:

A. *Pre-Questionairre (2-5m)*

- Age, Device experience and preference, Acupunture experience
- Captures demographic information for correlations with UI Sentiment

B. *Pre-Test (5m)*

- Quiz of 5 questions
- Paper test – draw point on ear map relating to question.
- 20 seconds per question – nearpod control on PC
- Different from post test but from same collection.

C. *Training (5m)*

- PUI E-learning with immersive environment-sandbox/practice with hint nodes
- E-learning with immersive environment/3D GUI.
- Traditional – Sheet with labelled points, Video or F2F presentation.

D. *Post-Test (5m)*

- Quiz of 5 questions
- Paper test – draw point on ear map relating to question.
- 20 seconds per question – nearpod control on PC
- Different from pre-test but from same collection.

E. *Post-Questionairre (2-5m)*

- UI Satisfaction
- UI Issues.
- Motivation to use UI
- Captures UI sentiment for correlations with demographic information.

IX. Implementation

Virtual Acupuncture, the Immersive application with LEAP motion interface, was developed as a final year project by level 6 student Dennis Ilie as part of the Bsc Hons Computer Science degree under supervision by Jeffrey Ferguson. The application was developed using Unity3D [25], a games engine middleware used for creating interactive software. Unity3D was used due to its capability to create and export interactive applications to a variety of platforms such as Windows, iOS, Android, and web platforms via WebGL.

A well as platform support, Unity3D also provides a range of input device support. For this Application we chose to use the LEAP motion device [21] for a PUI, as it tracks the fingers and hands over a small space. This fits well in front of a PC keyboard, and additionally could be fitted onto a head mounted display or tablet for variations.

This implementation uses the LEAP motion controller placed in front of a PC keyboard running a windows build of the Virtual Acupuncture application.

The application was programmed in C# in Unity3D, and a 3D model of the ear was sourced from Turbosquid [26] for interactive content.

The development was undertaken by Dennis Ilie, an undergraduate student in the Bsc Hons Computer Science course at the Universiy of Westminster under supervision and advisement of project leader Jeff Ferguson, Lecturer in Mobile and Pervasive Computing, and Aleka Psarrou, Head of Department. Initial requirements were investigated with the assistance of Lee Butler, Lecturer in Chinese Medicine and Acupuncture at the University.

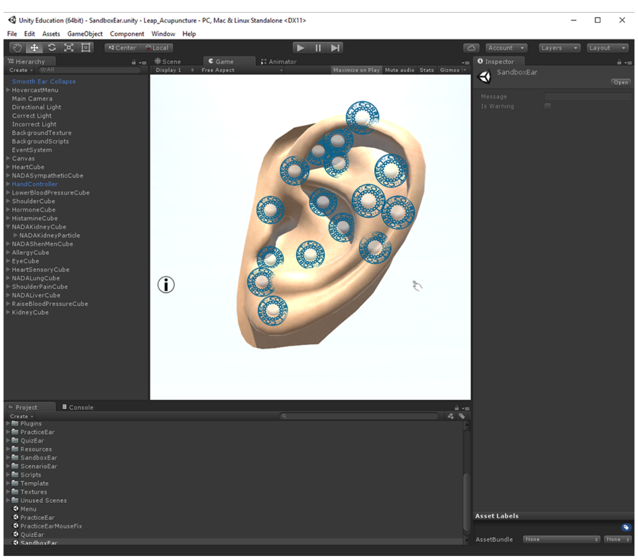

Figure 2. Sandbox Development screenshot for Ear NADA Protocol *(figure caption)*

For the PUI using the leap motion, the interface used is Hovercast [19], a VR interface software library available for the Leap motion controller. It is an arc-shaped, hand-attached, hierarchical menu interface that allows two handed navigation of a series of application choices. The point selection interaction is hand coded to detect mid-air "screen taps".

For the E-Learning and M-Learning interfaces, the built-in Unity 3D UI is utilized. This enables 3d world located buttons and interactive points. This interactivity can be built and run on windows or web platforms for the purpose of this study.

The Practice, Sandbox, and Quiz modes all exist in separate scenes accessible by a software interface. Practice and Sandbox are essentially the same, and offer freeform navigation and selection of areas on the body part with positive and negative feedback along with name and information for any positive selection. Visual hints in the form of blank spheres at point locations may be turned on and off.

C# scripting within the quiz mode enables a random selection of questions from a XML file to be accessed from the Unity interface. In this instance, we will use the same questions for each group's pre- and post-test, as they are naïve and should be directly comparable.

X. Experiment

For the experiment, as stated previously, there is not a full framework for comparison in place to the e-Learning without PUI and traditional learning system. This will come in a further paper. For the moment, this pilot evaluation of the PUI IE e-Learning system was carried out with 8 subjects, all students of the University of Westminster , and all without previous direct experience of the Leap motion controller used in the experiment or the NADA protocol for Acupuncture. The study took place at the University of Westminster London premesis, and each subject was tested individually. Each session lasted for approximately 20-30 minutes, and included a post-questionaire for UI sentiment. The questions were all multiple choice on a Likert scale of one to five (one being the least favourable answer and the five the most favourable answer). The evaluation focused on usability issues, system capabilities and system learning. All participants used the same apparatus.

XI. Data and Analysis

For the final framework, the mean change in score is to be compared among experimental groups (PUI e-Learning, e-Learning, and Traditional. At the moment we have data for this paper for the PUI IE e-Learning group, so we will confine our evaluation for the scope of this paper to the UI sentiment collected based on the Likert scales.

The overall UI sentiment view of the experiment is as follows:

TABLE I. TABLE FOR SYSTEM/UI USABILITY

System/UI Usability	Avg.
I think that I would like to use the UI Frequently.	2.375
I found the UI unnecessarily complex.	2.25
I think the UI is easy to use.	2.125
I think that I would need the support of a technical person to be able to use the UI.	2.25
I found the various functions in the UI to be well integrated	2.875
I think there is too much inconsistency in the UI	3.625
I imagine that most people would learn to use the UI very quickly	3.875
I found the UI very clumsy to use	3.625
I felt very confident using the UI	3.125
I needed to learn a lot of things before I could get going with the UI	2.125

TABLE II. TABLE FOR SYSTEM/UI CAPABILITY

System/UI Capabilities (Effectiveness)	Avg.
System UI Speed	3.125
System/UI reliability	2.25
System/UI tends to be noisy	1.875
Correcting your mistakes	2.5
Designed for all levels of users	4

TABLE III. TABLE FOR SYSTEM/UI LEARNING

System/UI Learning	Avg.
Learning to operate the UI	4.25
Exploring new features by trial and error	3.75
Remembering use of commands	4.125
Performing tasks is straightforward	3.625
Messages on the screen	4

TABLE IV. TABLE FOR SYSTEM/UI NAVIGATION

Navigation	Avg.
The UI navigation was easy	3.5
Navigation cues were clear and concise	3.5
The UI links were consistent	3

TABLE V. TABLE FOR MOTIVATIONAL USABILITY

Motivational Usability	Avg.
The UI incorporates novel characteristics	4.125
The UI stimulates further enquiry	3.875
The UI is enjoyable and interesting	4.375

TABLE VI. TABLE FOR INTERACTION AND SELECTION

Interaction and Selection	Avg.
The UI Interaction and selection was easy	3.375
Interaction/Selection cues were clear and concise	3.875
The interaction/selection links were consistent	3.625

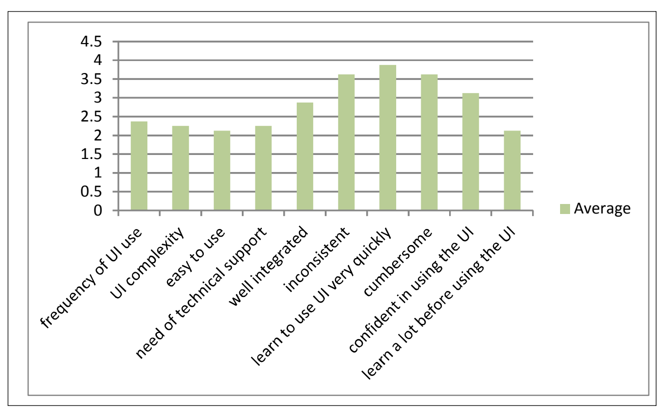

Figure 3. Bar Chart for UI Sentiment: System/UI Usability

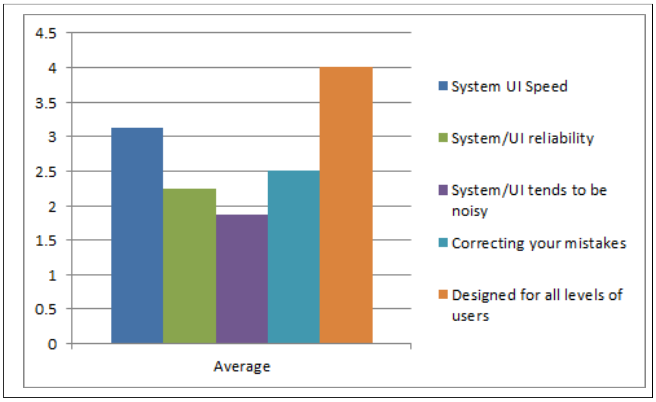

Figure 4. Bar Chart for UI Sentiment: System/UI Capability

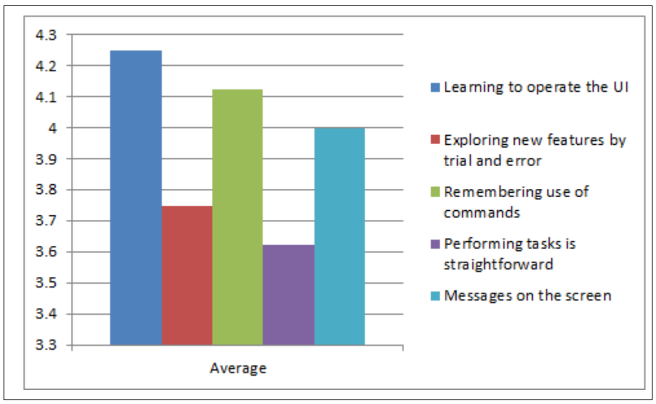

Figure 6. Bar Chart for UI Sentiment: System/UI Learning

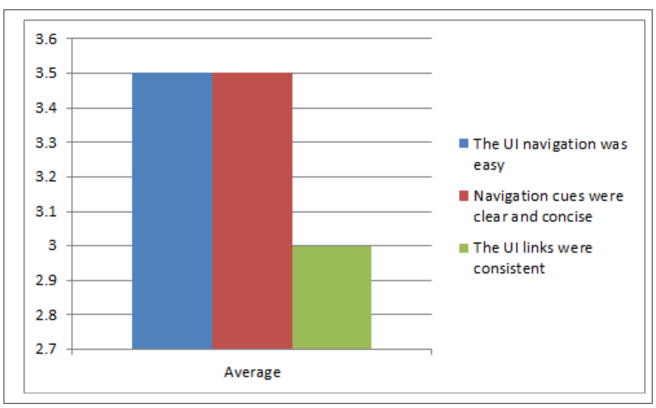

Figure 8. Bar Chart for UI Sentiment: System/UI Navigation

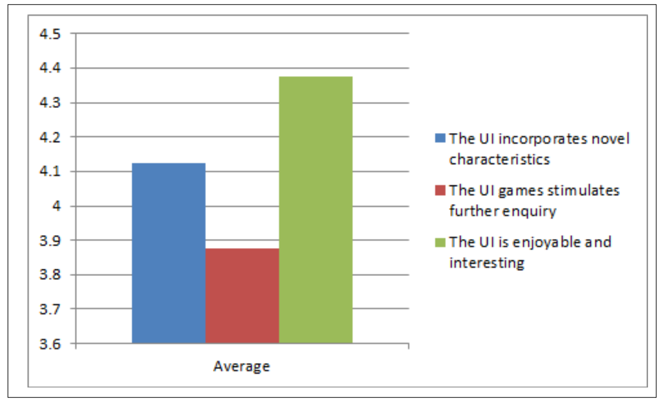

Figure 9. Bar Chart for UI Sentiment: Motivational Usability

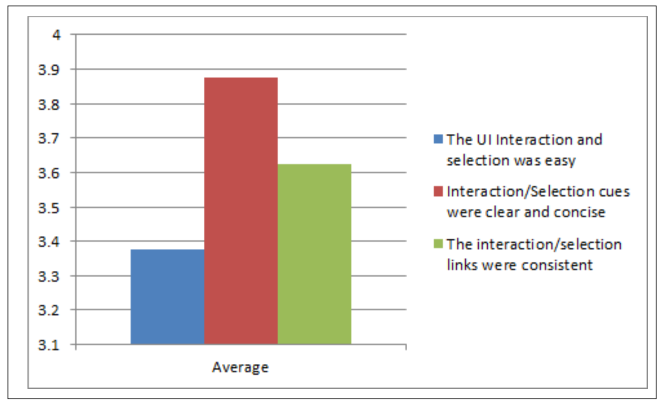

Figure 10. Bar Chart for UI Sentiment: Interaction and Selection

The data showed average responses in the Usability scale for ease of use, but with higher results indicating some inconsistency and clumsiness in the UI. At the same time, the highest result at 3.875 was for being able to learn the UI quickly.

UI Capabilities indicated a strong feeling that the UI was designed for all levels of users, and the other results indicated only an average level of noisiness, and average to good levels of speed, reliability, and error recovery.

The UI Learning appeared to be the strongest category for the UI, as all averages were above 3.5, indicating ease in learning to operate, explore features, remember commands, and get feedback from messages on screen. The lowest average Likert score at 3.625 was for straightforward performance of tasks.

Navigation of UI was above average, with the lowest score of 3 for consistency of links.

Motivation to use the UI was high, with 4.375 indicating the UI is enjoyable and interesting, 4.125 for incorporating novel characteristics, and 3.875 for stimulation of further enquiry.

Interaction and Selection feedback was only slightly lower, and seemed to indicate above average levels of ease, clarity, and consistency.

XII. Conclusions

Due to the small cohort and scale of the study, we would not like to come to any strong conclusions regarding the PUI interface for the IE e-Learning system. However, there were better than average results for UI Sentiment on the interface, especially in the important area of motivation to use the system and ease of use.

The framework described in this paper, as well as the results of the UI sentiment evaluation, indicate that there is a case to be studied around the quantification of PUI e-Learning benefits against those of e-Learning and traditional methods. There is scope and framework to continue with this study and also to iterate development on the various framework systems.

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