An Evaluation of Prototype VR Medical Training Environment: Applied Surgical Anatomy Training for Malignant Breast Disease

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Abstract. This paper presents an enquiry into the suitability of Virtual Reality (VR) technology as the principal training method for applied surgical anatomy. In this work we present the development of a prototype VR medical training environment and the evaluation results of preliminary trials aiming to identify the effectiveness of the system in the subject domains of anatomy teaching and surgical rehearsal, whilst acknowledging current training requirements.

Keywords. Anatomy, surgery, breast cancer, tutorial, semi-immersive, HCI.

Introduction

Recent studies have suggested that VR training methods shorten learning curves [1]. In addition current changes in anatomy and surgical training demand flexible availability of teaching resources. Increasing student numbers and the pressures from a growing curriculum have resulted in a reduction of effective anatomy teaching time and the accessibility of cadaveric materials to trainees has decreased [2]. In contrast educational research highlights the importance of visualization skills in anatomy learning [3]. Hence a cost effective, on-demand solution could be offered by developing a "VR cadaver". Contemporary attempts to train medical staff using 3D models were encouragingly positive [4, 5].

However previous studies involving 2D web applications and complex interfaces fuelled the development of a VR system emphasizing an interface that could effectively convey information to the user. Hence we developed a detailed 3D model to facilitate training. The model's complexity is adjustable to student requirements and is easily focused on specific training goals. Additionally, utilizing haptic interaction could improve the user's spatial awareness of complex structures [6].

The hypothesis behind this study suggests VR interfaces and holographic human body representation could convey appropriate information to the students in an accessibly interactive manner compared with available teaching resources [7].

1. Simulation Methodology

To evaluate the effectiveness of this tool we employed the VR facilities at the Digital Design Studio [8]. Our system incorporates real-time visualisation, gesture interaction with tactile feedback (CyberTouch™ glove) and is based on the Fakespace Immersive Workbench. We opted for this configuration for three reasons. i) The "Workbench's" table-projection surface resembles a surgical table. The trainees therefore experience contextual immersion. (ii) This semi-immersive system projects the 3D model into the user's space, allowing them to see themselves and other group members alongside the model. (iii) The interface is fully customizable to facilitate explicit utilities along with standard navigation. The training, evaluation and assessment materials were provided by the Royal College of Surgeons, Edinburgh. Guided by Consultant Breast surgeons we modelled a 3D representation of the torso, axilla and its contents. The nervous, venous, arterial and lymphatic systems depict accurately anatomical relationships. The detail level focused on the intercollegiate Membership of the Royal College of Surgeons (MRCS) transitional curriculum[9]. Our research focused on Human Computer Interface (HCI) and VR simulation development (Figure 1). The main objective of this activity-centered study [10] was to enhance and accelerate the assimilation of knowledge of surgical anatomy.

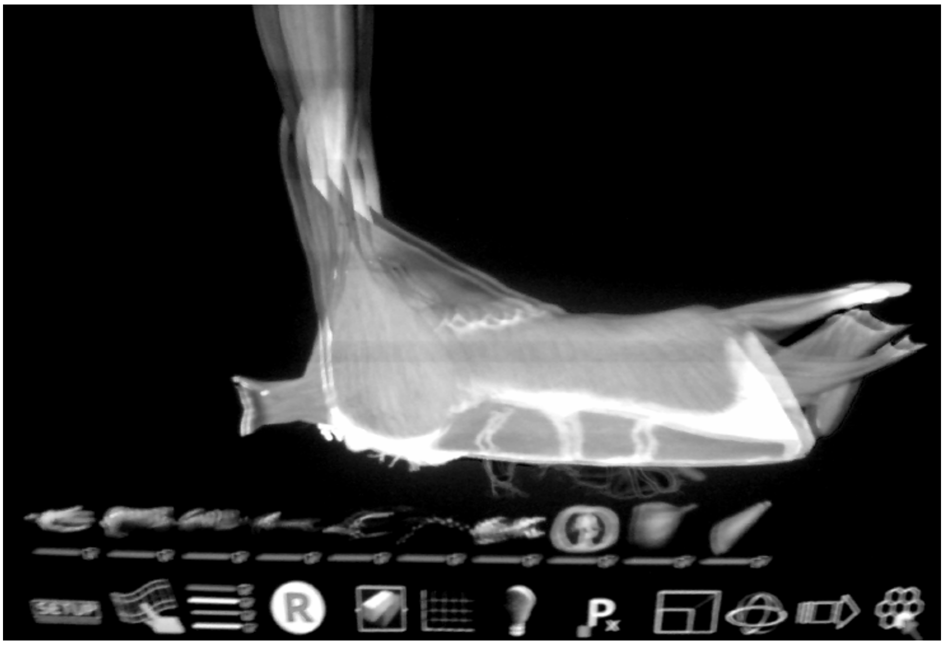

Figure 1: Screenshot from the VR interface.

2. Evaluation & Results

Twelve Postgraduate trainees (FY2) were selected and split into two arms. Both were objectively pre-assessed to ensure suitability. The first underwent a structured PBL anatomy tutorial augmented with the VR model (Figure 2). The second group took part in the same tutorial using traditional resources. The tutorials focused on applied surgical anatomy relating to malignant breast disease. Both arms completed a subjective user evaluation questionnaire and a multiple choice assessment structured to test candidates internal spatial understanding of common surgical approaches and complex anatomical relationships [11]. The subjective evaluation was an adapted Questionnaire for User Interface Questionnaire (QUIS) exploring perceived usability, engagement and value [12].

The results were processed to compare each arm against group and individual means, given standard deviations and confidence (p value 0.05). Grouped questions were compared to illuminate trainee's perceptions of their individual engagement, modified learning approach and internal 3D assimilation.

Table 1: Analysis of mean results of structured QUIS items exploring acquisition of 3D understanding.

3D Internalization	Question 1: I find I learn immediately as internal 3D model.
	Question 2: I find I have to work hard to create a 3D model internally.
Error Recognition	Question 3: I find I recognize mistakes in my understanding easily.
	Question 5: This approach makes me confident about my learning.
Communication	Question 4: I find it easy to discuss the anatomy with my facilitator.

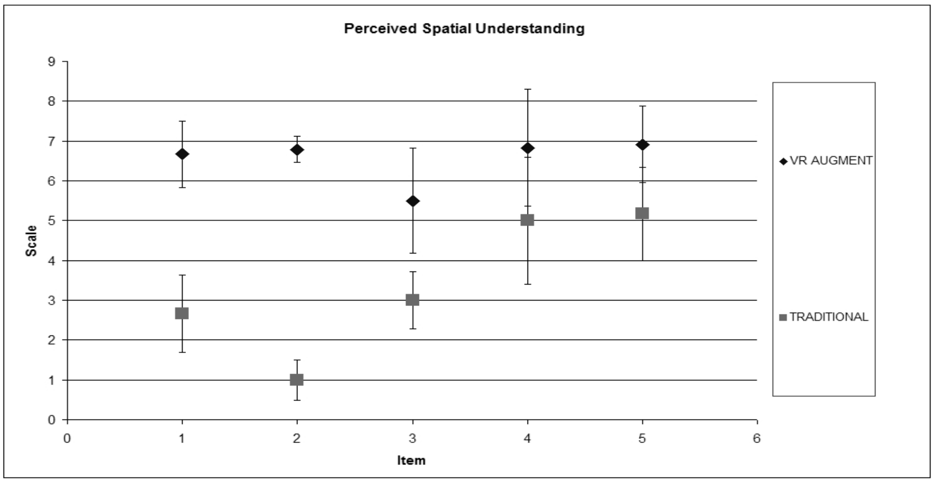

Figure 2: Analysis of mean results of structured QUIS items exploring acquisition of 3D understanding.

Figure 2 presents comparative data demonstrating whole group means attributed to items which explored spatial knowledge transfer and the facility each approach demonstrated in aiding the synthesis, appraisal and amendment of imparted anatomical relationships. Statistical analysis was limited by the small group size.

In addition item groupings demonstrated improved engagement, a reduced reliance on tutor support and higher levels of efficiency and accuracy in learning.

Significantly the VR arm showed higher scores in questions testing spatial relationships, specifically in the context of surgical approaches. However, overall results were balanced between the two approaches, with no significant difference between mean group performances. Figure 3 illustrates the mean results of MCQ questions structured to be "far", i.e.: requiring spatial understanding rather than direct interpretation of provided resources. In turn the same figure presents the similar overall performances (VR 61.25%, Traditional Resource 60.41%) between the two groups.

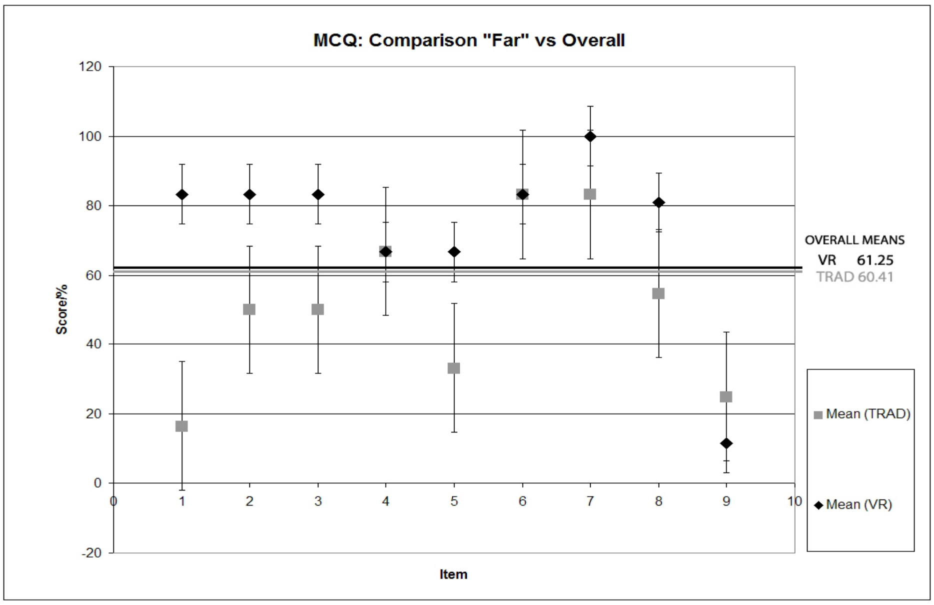

Figure 3: Mean results of "Far" MCQ items contrast with similar overall performance.

Interestingly the structured qualitative interview reinforced the positive outcomes of the MCQ "Far" results. Themes developed within the answers reflected trainee's enhanced confidence in their anatomical knowledge when able to interact and explore the VR models during the tutorials. Additionally the exploratory attribute of the system was commented upon. This was reported to enable users to illuminate areas of weaker understanding and fill knowledge lacunae.

The interviews also revealed recurring themes relating to the user interface. User's varied in the ease with which they were able to utilize the haptic tools, note that the specific interface was designed specifically to facilitate the preliminary investigation and it is our intention to incorporate users' feedback into future versions.

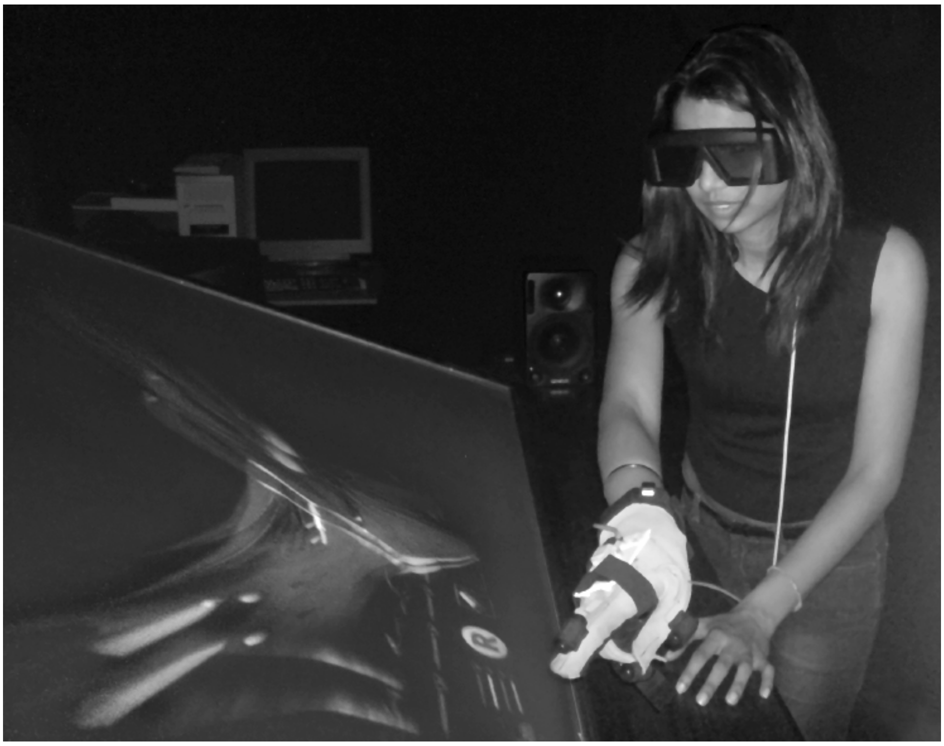

Figure 4: Surgical Trainee during the VR system evaluation.

3. Conclusions

In this paper, we described the design and development considerations of a VR environment specifically designed to integrate with current activity-based tutorials. The results were encouraging and suggest an enhanced synthesis of a spatial anatomical model by augmentation with VR.

However this preliminary inquiry highlighted practical considerations specific to validation for surgical education. This primary evaluation was encouraging but statistically limited by its small subject group. It is our intention to develop further the aforementioned system and improve portability in order to conduct larger studies.

From our experience in performing this study alongside an examination of current literature it seems clear that further work is required to create an empirical evidence base. This combined with the development of practical applications is required in order to bring VR into mainstream surgical education.

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