PHANTOM Prototype: Exploring the Potential for Learning with Multimodal Features in Dentistry

Jonathan P. San Diego[*]
J.P.San_Diego@kcl.ac.uk

Alastair Barrow[§]
A.L.Barrow@rdg.ac.uk

Margaret Cox[*]
MJ.Cox@kcl.ac.uk

William Harwin[§]
W.S.Harwin@rdg.ac.uk

ABSTRACT

In this paper, we will demonstrate how force feedback, motion-parallax, and stereoscopic vision can enhance the opportunities for learning in the context of dentistry. A dental training workstation prototype has been developed intended for use by dental students in their introductory course to preparing a tooth cavity. The multimodal feedback from haptics, motion tracking cameras, computer generated sound and graphics are being exploited to provide 'near-realistic' learning experiences. Whilst the empirical evidence provided is preliminary, we describe the potential of multimodal interaction via these technologies for enhancing dental-clinical skills.

Categories and Subject Descriptors

K.3.1 [**Computers and Education**]: Computer Uses in Education – *Computer-assisted instruction (CAI)*

General Terms

Design, Human Factors

Keywords

Technology-enhanced learning, haptics, multimodality, virtual reality.

1. INTRODUCTION

Educationalists are keen to bring multimodal interfaces into the mainstream because, for example, touch, through technologies such as haptic interfaces, could promote positive learning effects [1]. Haptic interface "concerns association of gesture to touch and kinaesthesia to provide for communication between the humans and machines" (p. 16) [2]. Also, other technologies such as stereovision (i.e. presenting a different view of the virtual scene to each eye to give natural stereoscopic depth cues) have been found to provide a richer 3D experience [1]. However, the capacity of current technology to precisely model varying multimodal feedback is still limited.

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[*] Centre of Flexible Learning in Dentistry, King's College London
[§] Cybernetics Department, University of Reading

We are developing a multimodal system, called PHANTOM (Personalised learning with Haptics when Teaching with Online Media). The PHANTOM project aims to contribute to the development and evaluation of Technology-Enhanced Learning (TEL).

This paper outlines the requirements from users (dental clinicians and students). It describes the different components and features included in the PHANTOM prototype. It presents a brief report about the opinions gathered from user trials. This paper begins with a brief background about the importance of the features.

2. MULTIMODAL INTERFACES IN DENTISTRY

There have been claims that there are positive learning effects from features that multimodal interactions offer. For example, the integration of features such as haptic feedback, stereoscopic vision, motion parallax, and realistic audio have been shown to introduce learning gains [1] [3] [4]. One of the applications of these multimodal features is in improving depth perception and spatial orientation in virtual reality.

Dentists must perform complex and precise spatial movements for which good judgment of depth is an essential requirement. It is well known that stereoscopic vision plays an important role in such tasks [5] but humans do not rely solely on one method of perceiving depth and in fact fuse together information from multiple sources to build up a 'complete picture'. For example it is known that haptic feedback can reduce the time needed to perceive depth [3]. Another very powerful depth cue which is not often utilised in human computer interaction is motion parallax. When a human's view point changes, objects that are nearer appear to move faster than those further away and with suitable tracking technology this effect can be recreated in a computer simulation.

Unfortunately, integrating multimodal features, such as the ones mentioned above, in a virtual environment has been a challenge for educators [e.g. 3]. As such the pedagogical affordances of these technologies are still limited due to technical constraints [2].

This research aims to investigate the extent to which multimodal interfaces can be applied to help train dental-clinical skills, specifically cavity drilling. We are interested in providing empirical evidence of the learning benefits for the multimodal features that are included in the PHANTOM prototype; some of which are: haptics, stereo vision, head-tracking (parallax), sound and collocation.

3. ANALYSIS OF USERS' REQUIREMENTS

We have involved users (dental clinicians) in specifying a list of requirements they would like a PHANTOM system to include (see

[6] for a full list of requirements). Users' specifications have confirmed the importance of the multimodal features of interest to this research. So far, specifications consisted of:

- Physical setup – includes suggestions about dental tools to be used, mounting of monitors, workspace size similar to that of a mouth, a device for users' fingers to rest on, and so on.

- Graphic screen display – includes 'near-realistic' image of an oral cavity, graphic dental tools, motion representations of hand and dental tools matching those in the physical setup, different angular views of an oral cavity relative to users and patients' position, and so on.

- Multi-sensory feedback – includes modelling of sound effects, tactile feedback, and colour change when: drilling at different pressure and speed of a dental tool, and when cutting different parts of a tooth.

- Data sources for modelling requirements – includes sources of actual 'data' to produce 3D representation of the oral cavity and tooth (i.e. CT scans, discarded bones of teeth and jaw).

Users have also specified visualizations which they suggested could help in their teaching. These included e.g. anatomical properties of teeth, different slices and sections of teeth.

4. THE PHANTOM PROTOTYPE

The first prototype of PHANTOM has been developed based on users' requirements [6]. Amongst others, the key physical components and features of the PHANTOM prototype include:

- A haptic device. This includes an actual dental handpiece. The position and orientation are matched to the graphic handpiece displayed on the monitor.

- A 3D stereoscopic display monitor. The user wears spectacles with polarised lenses. To produce the optical illusion of 3D perception, different visual signals are sent to the eyes.

- A motion-tracking camera. A typical digital camera is attached to the 3D monitor. The camera tracks a marker placed on the spectacles.

Figure 1. PHANTOM Prototype

5. USER TRIALS

A small number of users (15 clinicians including 12 dental post-graduate students) were invited to try the PHANTOM prototype.

Their opinions were gathered on the following system features. Below are a few examples of suggestions given by the users.

The physical setup. Most of the users who tried the system suggested that the setup needs to enable users to perform dental procedures without compromising their preferred posture (i.e. users looking down on a patient's face) and the need to operate at a specific point in space where they feel they have the best control of their fingers. *"I like the idea of having a finger rest. It helps."*

Head-movement tracking. All of the users liked being able to move their head naturally. One user commented: *"It is good. Isn't it? It is moving (referring to the graphic mouth)."*

Stereovision. Through the physical dental handpiece the users were asked to place the graphic handpiece on the surface of an object representing a tooth. The users seemed to be taking a longer time finding the tooth's surface when they were not wearing the lenses than when they were wearing the lenses.

6. CHALLENGES OF DEVELOPMENT

The opinions gathered from the users suggest that the development of the PHANTOM system needs to consider 'near-realistic' models of multi-sensory feedback as far as possible. However, it could be a challenge to achieve some of the requirements identified due to the limitation of current haptic technology.

The extent to which multimodal feedback already implemented in the PHANTOM prototype can positively influence learning has not yet been fully identified. But we will argue that this kind of system offers a potential to transform learning of dental-clinical skills.

7. ACKNOWLEDGMENTS

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