LocalAnesthesiaVR

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ABSTRACT

LocalAnesthesiaVR is a virtual reality training system for dental anesthesia, a clinical procedure every dentist must be competent with, and one that is particularly challenging to master throughout the demanding dental curriculum. This unique VR-based system provides learners with visual, auditory and haptic feedback enabling experiential learning in pre-clinical education.

CCS CONCEPTS

• **Human-centered computing** → *Pointing*; • **Hardware** → **Emerging interfaces**; • **Computing methodologies** → **Interactive simulation**; **Simulation by animation**; **Real-time simulation**; • **Applied computing** → **E-learning**; **Interactive learning environments**; **Distance learning**; **Computer-assisted instruction**.

KEYWORDS

Virtual reality, anesthesia, haptics, dentistry, oral surgery, interfaces, education, experiential learning, remote collaboration, simulation, anatomy, HCI, Oculus, hand tracking, analytics, assessment.

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1 INTRODUCTION

In this paper we describe the design and functionality of our VR system *LocalAnesthesiaVR* through the implementation of an Inferior Alveolar Nerve Block (IANB) on tooth 30 on a female head. We start by introducing our innovative use of virtual reality to supplement local anesthesia training in the context of pre-clinical dental education.

2 CLINICAL BACKGROUND

Applying local anesthesia injections is one of the most stressful procedures that dental students must master during their clinical training [Kary et al. 2018]. Dental injections must be applied swiftly and painlessly to the patient, and every practicing dentist must achieve a level of total competency in a relatively short time.

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Figure 1: A snapshot of the Inferior Alveolar Nerve Block (IANB) procedure being performed on a female head by a right-handed user.

Traditional methods of local anesthesia training involve students applying dental injections into a plastic manikin head model that provides unreliable and limited feedback. In addition, these plastic head models do not feature the complex anatomical features present in human anatomy and are therefore limited in a fundamental way.

3 IMPLEMENTATION

We designed and developed a state-of-the-art VR-based training module for local anesthesia injections with the goal of bridging the gap between pre-clinical and clinical education. Students in dental education programs can use this VR module for independent practice with or without supervision. They can practice every step of the procedure, from selection and assembly of the appropriate tools, to the actual application of the injection. Our VR system provides real-time, multi-sensorial feedback, including visual, auditory and haptic cues that guide the learner. It also features sophisticated 3D models of human anatomy including bone, soft and muscular tissue, circulatory, lymphatic and nervous systems that offer a richness of layered anatomy absent in traditional methods. Providing the learner with all these components in a fully immersive environment enables them to achieve long-term cognition.[Levine et al. 2013]

4 SYSTEM COMPONENTS

The *LocalAnesthesiaVR* system features the following components:

4.1 3D Models

The base for the 3D head model was generated from a CT scan of a real patient. The muscles, blood vessels, nerves, lymphatic system, and soft tissues were hand modeled on top of the skull. Hard surface models like dental tools, furniture, and clinical environment are

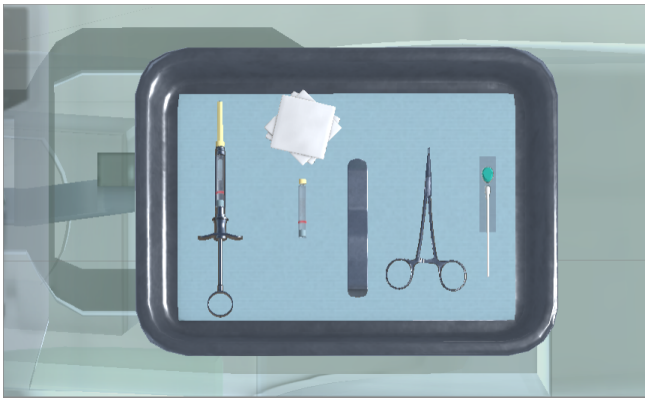

Figure 2: Required and optional armamentarium for the Inferior Alveolar Nerve Block (IANB) procedure.

modeled to scale with direct references from a dental operatory room.

4.2 Virtual Hands

Our virtual hands with custom hand poses provide proprioceptive feedback to the brain estimating the position of the user's real hands. This plays a crucial role in creating embodiment and immersion while interacting with various tools through the procedure. [Johnson-Glenberg 2018]

4.3 Control Pad

We implemented a virtual control pad that allows the user to make realistic physical adjustments such as the inclination of the dental chair and the height of the dental chair and tray. The user can also use the control pad to vary the degree of transparency of the patient's skin and muscle so that the relevant internal anatomy can be viewed.

4.4 Sound and Haptic Feedback

Our module provides auditory and/or vibrational haptic feedback at critical steps in the procedure. The user feels a vibration through the handheld controllers when critical steps are completed, such as when the user palpates key anatomical landmarks and when the orientation and depth of the needle is optimal.

4.5 Practice and Assessment Modes

The IANB module can be used in practice mode or assessment mode. In the former, ample feedback is provided through textual instructions, sound, and haptics. In the latter, very minimal to no feedback is provided, so that the user performs the task in a way that mirrors their clinical experience.

4.6 Error Counting

In practice mode, the user is allowed to make a set maximum number of critical errors before they are asked to restart the module from the beginning. In assessment mode, there is no such limit.

Figure 3: The *LocalAnesthesiaVR* system features sophisticated 3D models of human anatomy including bone, soft and muscular tissue, circulatory, lymphatic and nervous systems.

5 DATA CAPTURE

Multiple non-identifiabale data points (duration, hand dominance, session type, step outcome, answers to questions, errors, etc.), are captured from the beginning to the end of the module to analyze user performance and behavior.

A cloud hosted, NoSQL database was used to store, sync, and query user performance data.

6 CONCLUSION

A usability study conducted in October, 2020 involving 13 fourth-year dental students gave us indication that this VR-based training system could be useful when integrated into the pre-clinical curriculum, as hands-on practice opportunities for local anesthesia are very scarce. We are currently conducting an A/B study with 40 second-year students that aims to determine the degree of efficacy of acquired skills after using our VR training as compared to the traditional manikin-based pre-clinical training.

7 FUTURE WORK

Next steps in development include integration of multi-point haptic feedback, multi-user ability, and the implementation of a pilot program into the dental curriculum at New York University College of Dentistry and other peer schools.

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