Innovative user-centric design and engineering process to develop a part-task trainer for military medical training

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Abstract — Injuries to the head can result in a buildup of pressure behind the eye, causing a damaging reduction in blood flow (ischemia) to the retina and optic nerve. A simple surgical procedure, a Lateral Canthotomy and Cantholysis (LCC) can save the eyesight of troops and civilians injured in this way, if it is performed quickly. The retina and the optic nerve may endure approximately 90 to 120 minutes of ischemia before the potential of permanent vision loss. This paper will describe the innovative user-centric design and engineering process used to develop a part-task trainer to practice the LCC procedure. Early user interaction was critical in defining qualitative requirements and technical objectives. The role of user evaluations as well as the engineering process used to translate qualitative feedback into quantitative design and production metrics will be discussed.

1 Introduction

Eye injuries are common in combat, especially with the high prevalence of improvised explosive devices (IEDs). In fact, 186,555 eye injuries were reported by military medical facilities worldwide between 2000 and 2010 [1]. Many blunt trauma injuries result in compartment syndrome of the orbit. Compartment syndrome is characterized by a large build-up of pressure behind the eye which can prevent adequate blood flow from reaching the optic nerve and retina, resulting in ischemia to the retina and optic nerve. Compartment syndrome of the orbit is a condition that threatens vision. The retina and the optic nerve may endure approximately 90 to 120 minutes of ischemia before permanent vision loss occurs.

Fortunately, compartment syndrome can be easily treated through the administration of a simple procedure called a Lateral Canthotomy and Cantholysis (LCC). During the procedure, the built up pressure is released and blood flow is restored to the optic nerve and retina, thus saving the afflicted eye.

2 The Lateral Canthotomy and Cantholysis Procedure

The LCC procedure can be performed in the field with very few instruments. The curriculum at U.S. military medical training facilities support the instruction of the LCC procedure using PowerPoint slides and the limited use of live tissue trainers. There is no physical simulation model that allows trainees to practice the psychomotor skills necessary for competency development. In addition, no current civilian equivalent training model exists to practice the LCC procedure. As a result, there is a training void and this relatively simple procedure has not been employed by care providers. The purpose of this research was to develop a low cost, reusable, haptic training device to help combat medics develop and refine the skills that are required to perform the LCC procedure. The LCC training system is shown in figure 1.

Fig 1. The LCC training system.

The research team used rapid prototyping and the spiral development process to develop twelve mannequin heads and 300 replaceable eye socket inserts to support hands-on testing, evaluation, and analysis of the scientific, technical, and commercial merit of the LCC training system (figure 2). Civilian and military subject matter experts (SMEs) evaluated the prototypes iteratively and provided subjective feedback (assessments of whether the intraocular pressure produced by the trainer was accurate, too firm, or too soft) via a questionnaire. During their assessment of the LCC training system, SMEs also documented whether they were able to perform the critical anatomy-dependant tasks that are required during the LCC procedure.

Empirical test methods were developed and utilized to translate subjective feedback into quantitative design and production metrics (figure 3). This innovative methodology was critical in assessing whether a requirement of the simulator (e.g., tactilely-accurate) had been met. A survey of pairwise comparisons of requirements and design goals was used to reconcile SME inputs and quantify the relative importance of each design goal of the LCC training system (published in [2]). This study enabled the research and development team to prioritize requirements and focus on the top design features identified by the user community to be incorporated in the system.

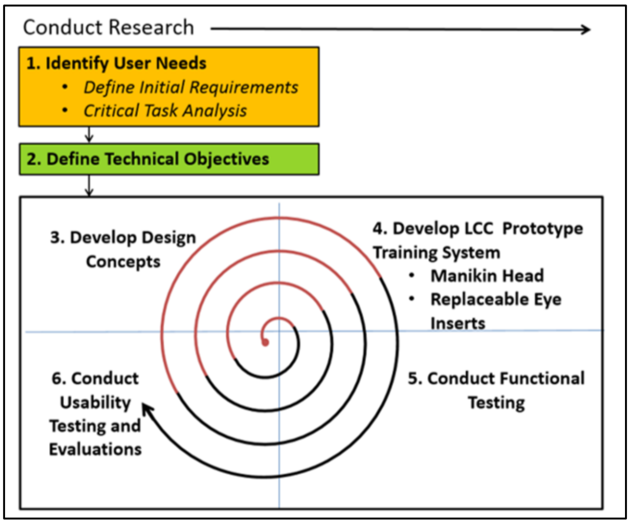

Fig 2. The spiral development model that was followed during the definition of the LCC training system [3].

3 Challenges

One challenge faced in the design and development of the LCC prototype includes enhancing the fidelity while cost-effectively manufacturing the replaceable eye inserts. The goal is to provide the training audience with a capability to practice multiple times as needed to develop the required psychomotor skills for the LCC procedure, thus improving trainee's self-efficacy. This training system could potentially support education and training of prolonged field care – caring for a casualty over an extended period of time with limited resources.

Fig 3. The empirical testing aparatus that was used during evaluation of the LCC training system [4].

4 Take-aways

The benefits and takeaways of this presentation include the innovative methodology that was used to define qualitative medical requirements and technical objectives, and their translation into quantitative design and production metrics. The role of user evaluations in the rapid prototyping process, as well as the methods used for de-conflicting design goals will benefit other research teams in the development of part-task trainers. Lessons were also learned with respect to 3D printing and small batch development, which allowed the design and development team to rapidly implement design changes and produce updated eye inserts for further evaluation and testing.

5 References

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