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Tactile Feedback Wearable during a Surgical Simulation Task: Pilot Study Indicates No Distraction, Frustration or Performance Decrement for Users

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1 Background

With advancements in surgical techniques, patients have experienced improvements in health and recovery outcomes. However, about 87% of laparoscopic surgeons [1] and an increasing number of surveyed allied health professionals [2, 3] report musculoskeletal symptoms. Medical practitioners and human factors engineers have highlighted the "hostile" and "dangerous" operating room (OR) environment [1, 4, 5]. With increasing technology and surgical case complexity, physical demands for surgical team members will continue to increase due to circumstances such as technology restricting posture, taking up working space and more team members working around smaller surgical incisions [6]. There is widespread concern that these medical professionals' work is unsustainable for safe and healthy patients and surgical team members.

Surgical team members can benefit from posture improvement during surgery; however, direct postural feedback may be difficult during their work due to the high visual and auditory stimuli during surgery. The tactile modality has been recently explored as a method to provide additional information without interfering with cognitive resources dedicated to visual and auditory pathways [7]. Tactile devices have successfully been implemented in high-stress environments, e.g., military, healthcare, and rehabilitation with a resulting improvement in performance [8-11]. Vibrotactile feedback has been specifically implemented in the healthcare field for improved performance by 31-75% anesthesiologists during simulated tasks [10]. Additionally, it has contributed to improved postural control in rehabilitation patients[11]. Despite success in other application areas, the potential of tactile devices for improving healthcare workers' safety and performance remains unexplored. This study is a part of a larger project to design a wearable device that provides real-time vibrotactile feedback for preventing fatigue and musculoskeletal disorders for healthcare workers in the workplace.

This specific aim of this study is to measure distraction, frustration, and performance during a surgical simulation task performed with and without vibrotactile feedback. This is a test of initial feasibility of vibrotactile feedback for use in training proper ergonomics for surgical team members. The researchers hypothesize that there will be some distraction with the vibrotactile feedback wearable but no frustration or performance degradation during the basic simulation task.

2 Methods

2.1 Device. The pilot version of the feedback system consisted of two parts. First, a small tactor was placed inside the waistband of the participant's pants in the middle of their lower back (near L5/S1)[12]. Second, inertial measurement unites (IMU's; APDM, Inc., Portland, OR) were used to simulate the final device system (IMU's programmed with a tactor) for ergonomic posture risk detection. However, postures were not recorded during this study.

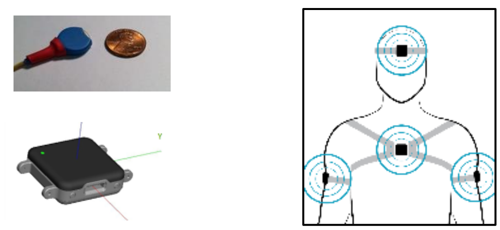

Figure 1. (Left top) Tactor, (Left bottom) IMU (Right) Anterior view of motion capture setup: IMUs with grey straps

2.2 Participants. Eighteen (12 Male) first year surgical residents with minimal task experience were recruited and randomized to either completing their first half or the second half of a surgical simulation task with the vibrotactile feedback.

2.3 Surgical Simulation Task. The task chosen for this study was the fundamentals of laparoscopic surgery (FLS) peg transfer task[13]. Peg transfer is a basic laparoscopic skills task that tests manual dexterity, hand-eye coordination, and depth perception in the laparoscopic surgery environment. Using a laparoscopic FLS Skills trainer with lights, a camera, and screen (Figure 2; Limbs & Things, Savannah, GA), participants operated laparoscopic graspers to pick up six small objects individually and transfer each from the six pegs on the left, to their right hand, and place each on the six pegs on the right. Then this was reversed moving them from right to left. The participant viewed the task completion on a display screen.

2.4 Protocol. All participants received verbal instruction on how to perform the surgical simulation task prior to task completion. At that time, a researcher explained to each participant that they would receive a vibrotactile feedback stimulus every 10 seconds with no accompanying visual feedback. When they felt this feedback they needed to respond with "left", "right", or "none" signifying which grasper hand held an object. This verbal confirmation both demonstrated that participants felt the vibrotactile feedback and simulated a cognitive response. This mimicked the application where participants would be expected to note and process vibrotactile feedback then respond with a posture change. This verbal confirmation was incorporated in order to get a better sense of the impact (from distraction or frustration on performance) of the feedback during the postural adjustment application. Since this was a short task with relatively low physical exertion by the participants, the feedback was provided at 10 second intervals instead of waiting for participants to assume unhealthy body postures. Half of the task was completed with the feedback and half without, randomized to the first or second half with feedback, in order to control for performance, distraction, and frustration that could differ between the two halves. Participants were timed and each task half was limited to two minutes. Participants completed a modified NASA-TLX questionnaire [14] using the frustration, physical demand, distraction, and mental demand subscales for each task half.

Figure 2. (Left top) FLS Peg Transfer task with objects on the right six pegs. (Left bottom) Surgical Grasper. (Right) FLS Surgical Trainer set up with task and display screen.

3 Results

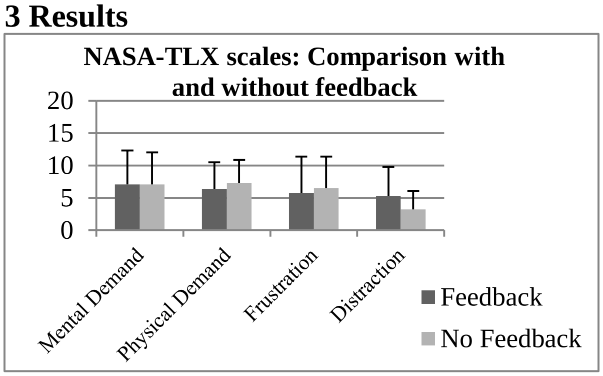

Figure 3. Workload comparison during surgical simulation task. Scale of 1-20 for NASA-TLX subscales.

Results from a one-way ANOVA (all at $\alpha=0.05$) indicated participants reported no statistical difference in mental demand ($p=0.498$), physical demand ($p=0.974$), frustration ($p=0.707$) or distraction ($p=0.098$, Figure 3). However, distraction stands out as being closer to statistical significance. Performance time without feedback was 62.3 seconds (standard deviation=26.5) did not differ statistically from the 63.9 seconds (standard deviation=29.1) with feedback ($p=0.863$) in an ANOVA.

4 Interpretation

Our results from the tactile feedback tasks are consistent with previous work in anesthesia and rehabilitation that found the tactile modality can be used to unobtrusively provide feedback to anesthetists and improve and postural control without reducing performance [10]. This work is limited to surgical simulation tasks and will need to be tested in the field (surgical training and practice settings) in order to fully understand the potential of this technology. Currently distraction seems to have the largest potential of impact in the application setting and could be masked or exaggerated by the focus required for training and surgical practice.

Future work will be focused on tactile feedback for awkward and sustained upper body postures. Training in good ergonomic practices such as improved upper body posture could prevent poor musculoskeletal health habits. Since a vibrotactile feedback modality has been successful in improving performance in healthcare [10] and this study has not indicated significant performance decrement, this feedback method can be pursued for surgical team member posture training. Continued research is needed for feedback that is job- and task-specific for preventing musculoskeletal disorders.

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