Sensing and Visualization Tools for Objective Assessment and Debriefing of High-Risk Neonatal Resuscitation Training Scenarios

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Abstract: The medical field has heralded the use of simulated scenarios as a highly cost-effective approach towards improving team performance. We present TeamVis, a set of tools for sensing and visualization of objective team performance in a simulated medical scenario. TeamVis helps teams, instructors, and researchers in observation, analysis, and evaluation of team behavior. The current system supports analysis of team movements and verbal communication. The system has potential to provide deeper insight into team performance, enabling design of more effective simulation training scenarios. Furthermore, the observed metrics can aid trainee debriefings by providing another mechanism for learning through self-reflection.

INTRODUCTION

In team training, simulations are often used to practice dangerous and difficult tasks in a safe, controlled environment1-4. After a simulation, team members conduct debriefings (or after-action reviews) to review team interaction and performance, highlight successes and failures and identify specific suggestions for improvement in future scenarios (real or simulated). Although simulations and debriefings are extensively used in modern team training, their effectiveness is limited by a lack of standardized, unbiased, objective metrics for assessing team performance. Objective metrics are needed for “soft” skills, such as communication, leadership and teamwork. The current effort addresses this lack of objective performance metrics by developing TeamVis, a set of novel behavioral analysis tools that capture and analyze team behavior to facilitate 1) discovery of new objective metrics of team success, and 2) assessment and review of team behavior and competency.

Importance of Teamwork

Medical care is a team effort where effective performance hinges upon the ability of teams to effectively work in complex, dynamic conditions. Communication, coordination and co-operation are vital to care5, especially in such complex service lines as operating rooms. During teamwork, the tasks an individual engages in are interdependent with peer tasks. Thus, individual team members must adapt their own inputs and efforts to those of their teammates to accomplish larger goals. Recent research highlights the need for understanding how teamwork helps improve safety and patient care quality6. Thus, the challenge with respect to teamwork is how to turn groups of clinical experts into expert teams. To address this challenge, we focus on developing technologies to identify and provide feedback on specific behaviors that lead to improved teamwork7.

Team Behaviors

TeamVis is designed for use in training neonatal resuscitation, a high-risk medical scenario that requires teams to work together to stabilize a newborn. Successful performance hinges on both the medical knowledge and skills of the individual health workers as well as the ability of the team of health workers to 1) smoothly establish and transfer leadership, 2) use closed-loop interaction to facilitate clear and specific communication, 3) maintain situational awareness, and 4) create a shared team mental model of the task and team7. In the long term, TeamVis aims to enable exploratory analysis and assessment of these four factors within the neonatal scenario. This paper focuses on the first two elements: leadership skills and closed-loop communication.

Leadership Skills: We enable analysis of leadership skills via capture and display of team leader movements, a proxy for leadership ability. Movement is a proxy for leadership ability because poor leaders tend to move about the room to do the tasks of others, rather than delegating tasks and supervising each team member.

Closed-Loop Communication: Clarifying and confirming requests or statements stated by others is closed-loop communication9. For example, the following transcript contains closed-loop communication:

Jessica: Emily, what is the pulse?
Emily: The pulse is 78.
Jessica: The patient’s pulse is 78

In this example, Jessica requests the heart rate. Then, Emily provides the heart rate to Jessica. Jessica closes the loop by restating the pulse for the team. The confirmation significantly decreases the chance of the leader or other team member making a clinical mistake that harms the patient.
Unfortunately, teams often use open-loop communication. For example:

Jessica: Emily, what is the pulse?
Emily: 78
Jessica: Emily, what is the respiration rate?

Emily’s response of “78” is open-loop because she does not clearly indicate that she is responding to Jessica’s request. Thus, Jessica or other team members may confuse Emily’s response to be respiration rate, or some other quantity of interest. In addition, Jessica does not request a confirmation or clarification from Emily. If Jessica heard 68 instead of 78, she might make a medical decision based on incorrect information, and the patient could be harmed. Thus, closed-loop communication is preferred to open-loop communication because it clarifies communication and helps the team maintain a consistent and shared mental model of the scenario.

METHODS AND MATERIALS

System Architecture
TeamVis consists of two modules, TeamCapture and TeamDebrief. TeamCapture uses sensors to record the behavior of trainees. TeamDebrief enables analysis and visualization of recorded behaviors (Fig 1).

I. TeamCapture

TeamCapture captures digital representations of team behavior for further analysis in TeamDebrief. A 360-degree camera attached to a support beam of the infant incubator captures a panoramic video of the simulation. The camera captures video at full HD resolution (1080p) at 30fps. The camera is tethered to a computer, where video of the simulation is stored.

TeamCapture also integrates a speech recognition system to enable capture of all team dialogue. During training, each member of the team wears a custom wireless microphone. Giving each team member a wireless microphone simplifies speech processing by providing separate audio channels for each team member. Each team member’s audio is passed to a speech recognition process that transforms the audio into a personal text transcript, with timestamps for each utterance. The transcripts of each team member are then combined to form a complete verbal transcript of the training scenario.

The heart of the custom wireless microphone system is the Raspberry Pi (RasPi) microprocessor\(^\text{10}\). The RasPi is a complete System on a Chip. It integrates an ARM11 700MHz microprocessor, 512MB RAM, an SD slot for storage, and two USB ports to allow attachment of external adaptors. We add two external adaptors, one for microphone input and one for WiFi. The microphone is used to capture the wearer’s speech and WiFi is used to transmit speech to the cloud-hosted “Nuance 360 Speech Anywhere\(^\text{11}\),” a commercial speech recognition system frequently used in medical environments. Informally, we have observed over 90% accuracy in the output from “Nuance.” As the user speaks, the “Nuance” API sends speech to Nuance servers where it is transcribed and sent back to TeamCapture in real time. Transcribed speech is time-stamped based on the arrival time.

II. TeamDebrief

TeamDebrief integrates four tools for review and analysis of team behavior data collected by TeamCapture (Fig 1).

1. Transcript: The transcript tool integrates multiple analyses of the training session’s speech content. First, it lists the complete verbal transcript of the interview. Every utterance by every team member is listed, with timestamps and team member name, in chronological order. Second, the user can search for keywords in the transcript. Keywords are highlighted during search. This allows the user to quickly identify particular moments in the training session (e.g., search for “suction” to identify if and when a team member calls for suction). Third, the verbal transcript highlights open- (red) and closed-loop (green) communication (described below), which allows users to quickly identify the relative frequency of keyword as well as individual proficiency levels.

2. Word Cloud: The word cloud\(^\text{12}\) is a well-known visualization technique for seeing the relative frequency of words in text. Words used more frequently are larger in the visualization. Here, we adopt the word cloud to provide insight into the frequency of different types of requests and responses in the transcript. TeamDebrief can also display a word cloud for each team member, thus providing insight into the speech behavior of individuals.

3. Video Timeline: The panoramic video stream is shown in a window and can be played back in real-time. A timeline is displayed below it, allowing the user to seek to any moment in the video non-linearly. The timeline can also be annotated with bookmarks for quick access to specific moments of interest. Lastly, the video has a template matching motion tracker\(^\text{13}\). The user can select a region of interest with the mouse, and TeamDebrief will track the movement of this region in the video. This allows a user to analyze the motion of individuals.

4. Performance Report: The performance report lists basic statistics, such as the number of times help is requested; the percentage of speech that is closed-loop; and the top ten words used in the training session.

Detecting Closed-Loop Communication
To enable the four tools described above, TeamDebrief processes transcript data to identify open- and closed-loop
communication, frequency of words, and call outs related to our medical scenario (Fig 2). Standard text analysis techniques are used to extract this data. Due to space constraints, we only discuss detection of closed-loop communication here.

We use a heuristic text-processing algorithm to detect closed-loop communication. First, we remove filler words, such as “the,” “it,” and “there,” from each utterance. Filler words do not contribute to the semantics of each utterance. The remaining words of an utterance are then considered keywords. Keywords could represent a request made to a team member (e.g., “suction”) or information provided back to a team member (e.g., “BP 100”). Each keyword in the utterance is then matched to up to four subsequent utterances from other team members. If the same keyword is found in subsequent utterances, it is likely that the subsequent utterance is in response to the first statement, and thus represents closed-loop communication. In the closed-loop example discussed above, “pulse” is the shared keyword in Jessica and Emily’s statements. Thus, all of their statements would be marked as part of a closed-loop dialogue.

CONCLUSION AND FUTURE WORK
The next stage of this work is user-centered iterative design and testing to determine the validity and efficacy of TeamVis. We plan to test the system among all stakeholders (team leaders, team members, instructors, and researchers) to determine how sensing and visualization can be leveraged to aid development of more objective team performance measures.

More work is also needed to incorporate additional behaviors for analysis. Attention-related behaviors, such as eye or head gaze, could provide insight into how the focus of each team member changes over the course of the scenario as well as who they look to for leadership. Likewise, a deeper semantic analysis of the raw audio and transcript could help measure the stress level of team members and whether critical steps in the neonatal resuscitation scenario, such as calling for help, are done. In addition, we aim to automate and enhance movement analysis using motion history images.

In the long-term, we are interested in applying immersive virtual reality to the review of these scenarios. Specifically, we would like to enable team members to step inside a life-size 3D recording of the training session (Fig 3). Immersive interaction with the recorded training session may help trainees see how their behavior affects the team. Furthermore, it could enable new kinds of after-action review, such as allowing a leader to see a scenario unfold from the perspective of another team member.

REFERENCES

ILLUSTRATIONS

Fig 1: User Interface (UI) of TeamVis System

Fig 2: TeamVis Architecture
Fig 3: Concept art demonstrating immersive debriefing of a team medical scenario in the Operation Room (OR)