WEARABLE SIMULATOR FOR ENHANCED REALISM

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Abstract

Medical simulation mannequins are useful prototypes that are able to emulate a wide range of physiological features in order to provide the most optimal experience for medical residency and EMT trainees to learn from. Although many of these prototypes are currently available in the market, very few of them introduce the element of human interaction. Furthermore, in today's world, doctors often lack key human interaction skills which in turn affects their interaction with patients. The team was tasked to create a wearable simulation prototype that shall be worn by an actor in order to enhance the realism of a routine medical assessment of a patient to create a more in-depth and interpersonal experience. The wearable simulation prototype needed to be in the form of a vest and be able to simulate vitals such as heart pulses and respiration noises. Included in these sounds will be abnormalities in normal heart pulses and respiration noises that allow medical trainees to practice diagnosing conditions and assessing them once identified. The team's research focused on the normal and abnormal sounds produced by the cardiovascular and respiratory systems, the optimal vest for the storage of the electrical hardware, and the most efficient electrical design for the accurate representation of the sounds. The final vest design combined the Condor Ballistic Vest, Wireless with Bluetooth electronics design, and fake skin obtained from a past simulator mannequin. The final prototype was tested based on the accuracy of the sounds displayed and comfortability and will also be judged by our client. The test results concluded that there was not a significant difference between the sounds produced by the speakers on their own compared to through the fake skin. Furthermore, through testing, we modified our design to include only a front panel of skin attached. The two parts are attached by means of velcro straps on the top and sides, which allows for increased adjustability and comfortability. In the future, further components could be incorporated into the vest to allow for an even more immersive and realistic experience. Additionally, this design could potentially be tested against the Avkin model to illuminate potential further improvements.

Motivation

In the market today, there are numerous simulators that are being sold to hospitals and medical clinics. These simulators are adult full-sized mannequins that are capable of playing accurate heart and lung sounds of certain conditions, including tachycardia, bradycardia, arrhythmia, rales, and many others. They allow these trainees to experience the high pressure environment of being in the ICU, ER, or OR by performing various procedures on these mannequins. While they are beneficial in the different functionalities and features that each of them have, they lack one main component: the element of human interaction. Our goal was to take all the advantages that these simulators have and create a wearable simulation device where the incoming medical workers can feel the presence of a real human being. From the perspective of a doctor, not being able to experience a living patient in your midst and instead having a mechanical simulator with built-in audio quotes can cause difficulties as they begin to transition into the life of medicine. Our vest simulator is one way that students can execute procedures to simulate a condition while also keeping the touch of human interaction.

Background Research and Current Designs

- Background Research
  - Most of our team's research was done on heart and lung conditions which include tachycardia, bradycardia, and rales. We intend on using the information we found on those conditions and incorporate them into our wearable simulator, We will do this by playing heart and lung sounds for the medical trainees which help simulate these conditions
- Current Designs
  - SimMan by Laerdal Medical (**Figure 1**)
    - Adult full-sized mannequin intended for medical students and EMTs to practice performing simple procedures, including measuring blood pressure, reading EKGs, and monitoring oxygen flow.
  - Simulaids Smart Stat Basic with IPAD by Universal Medical (**Figure 2**)
    - Adult full-sized mannequin helping students function under high pressure environments, even outside of the hospital. Some of its key features include Advanced Airway Management System, Emergent Heart and Lung Sounds, and Pulse Points
  - Avkin Wearable Simulators (**Figure 3**)
    - A wearable skin vest that allows for more interactive simulations between medical trainees and an actor. The vest is capable of simulating an IV, Urinary Catheterization, and Central Line procedures

Figure 1. SimMan 3G from Laerdal

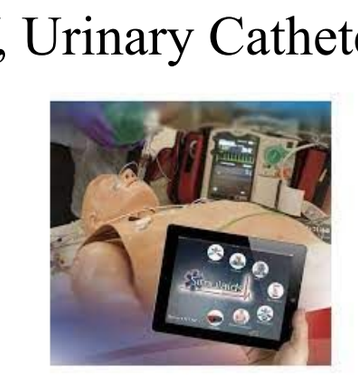

Figure 2. Simulaids Smart Stat Basic with IPAD

Figure 3. Avkin Vest

Design Criteria

First and foremost, our client gave us a budget of $500 to carry out this project, and his main concern was that we create a wearable simulator that is easy to use for incoming medical staff. Our group utilized two separate design matrices to determine the best design for this project: a vest design matrix and an electronics design matrix. Below, we highlight the main factors that swayed us in the direction we took.

- Vest design
  - **Comfort:** The actor should be capable of wearing the vest for 1-2 hours straight without experiencing any agitation or discomfort during the simulation.
  - **Durability:** The wearable simulator should be able to withstand 8-12 hours of weekly use for multiple years
  - **Output potential:** The vest allows us to implement the electrical components (wires and speakers) without causing any interior issues
- Electrical design
  - **Ease of Use**: Incoming medical staff and clinical simulation technicians should be able to run simulations frequently and with little to no issues.
  - **Output accuracy:** When lung and heart sounds are being played, the medical students should be capable to hearing those sounds clearly as if they are listening to a human heart or lung through a stethoscope

Design Criteria	Weight	Condor Ballistic Vest		Long Sleeve Vest		Add-On Version	
Durability	30	5/5	30	3/5	18	4/5	24
Output potential	15	4/5	12	4/5	12	5/5	15
Adaptability	15	3/5	9	2/5	6	5/5	15
Feasibility	10	5/5	10	2/5	4	3/5	6
Safety	10	5/5	10	4/5	8	4/5	8
Comfort	5	3/5	3	3/5	3	2/5	2
Aesthetics	5	2/5	2	4/5	4	3/5	3
Sterilizability	5	5/5	5	2/5	2	3/5	3
Cost	5	5/5	5	2/5	3	2/5	2
Total	100		86		60		78

Table 1. Vest Design Matrix. Preliminary Designs are compared based on the given design criteria.

Design Criteria	Weight	Dial Controlled Speakers		Wireless/Bluetooth		Wired to Computer	
Ease of Use	25	3/5	15	5/5	25	3/5	15
Output Accuracy	20	4/5	16	4/5	16	4/5	16
Durability	15	3/5	9	4/5	12	3/5	9
Feasability	15	2/5	6	4/5	12	3/5	9
Adaptability	10	3/5	6	3/5	6	3/5	6
Cost	5	3/5	3	3/5	3	4/5	4
Motility	5	4/5	4	5/5	5	2/5	2
Safety	5	3/5	3	4/5	4	2/5	2
Total	100		62		83		63

Table 2. Electrical Design Matrix. Preliminary Designs are compared based on the given design criteria.

Fabrication

- **Condor Ballistic Vest:** The selected vest for our final prototype was utilized as the main component of our design, and initially served as the means for housing the electrical portion of the wearable simulator. After testing, we ended up connecting the speakers directly to the skin. The velcros and various straps were optimized to anchor the speakers and fake skin to promote the enhanced realism quality of the prototype.

Figure 4. Initial installation of speakers to vest

- **SimMan Fake Silicone Skin:** Fake silicone skin was provided by the Clinical Simulation Center of the UW Health University Hospital for aesthetic purposes. The silicone skin was wrapped over the Condor ballistic vest in order to create a layer between both components for the placement of bluetooth speakers. Velcro with an adhesive was pasted onto the fake skin to help in the wrapping of the vest, with velcro side joined with the vest's velcros and the adhesive side stuck onto the skin's surface.
- **Bluetooth speakers:** Bluetooth speakers were used to display the desired heart and lung sounds requested by our client. Six speakers were used in total, each being placed on specific parts of the skin according to the location where certain heart and lung sounds can be typically heard in a patient. Three speakers were used for displaying heart sounds and three were used for displaying lung sounds. One bluetooth speaker was placed in the upper chest area with the purpose of playing tracheal and bronchial sounds. Two other speakers were placed in the left and right sides of the torso each assigned for each lung and have the purpose of playing vesicular sounds. Three speakers were placed in the left portion of the chest each according to different regions for sounds in the heart (mitral, tricuspid, aortic, pulmonary). Small pieces of velcro were pasted to each of the speakers in order to connect the speakers to the inside of the skin.
- **Software and Sounds** The sounds that will be projected through the speakers have the ability to be played from a mobile device or computer via wireless bluetooth connection. The speakers were calibrated and would have to be connected to the desired device that will be used for each simulator use. Multiple devices were used to complete the synchronized functioning of all the speakers.

Final Prototype

Based upon observations that arose during testing, we decided to use only the front piece fake skin and attach it to the vest. The overall design incorporates velcro straps and hooks to allow for adjustability and comfortability (**Figure 9**).

Furthermore, the bluetooth speakers are connected via velcro strips to the inside of the fake skin to allow for easy external identification as well as stability (**Figure 10**). Each speaker has the ability to connect via bluetooth to a device, allowing the respective sounds to be played. Finally, the palpable pulse simulates the patient's pulse, which can be detected and read by the medical student or EMT trainee.

Figure 9. Final Prototype being worn with pulse monitor and adjustable clips

Figure 10. Bluetooth Speakers Integrated on the Inside

Testing and Results

To begin our testing process we tested all of our electronics to ensure that they were adequate for our purposes. For the first test we ran sounds on the different speakers and haptic feedback device, and made sure the interactions between all the components ran smoothly. To pass this initial test, the speakers needed to play the correct sounds at the correct time in the correct location and the haptic feedback device needed to play at the correct pace. This test was considered a pass.

One of the biggest criteria of our client was that the device was required to work for a long period of time. To fit his needs the speakers needed to be able to function for 5 hours. The speakers were each left on for a period of 8 hours playing music, and all 3 successfully stayed charged and played music during the whole duration of the test. This test was considered a pass.

Another important criteria for our client was that the vest had to be comfortable but also realistic. Upon initial evaluation, the vest didn't look very realistic. Therefore, we got fake skin to put over the vest. With the skin over the vest it was very hard to wear for an extended period of time, so we decided to only put skin on the front. We proposed that 10 people should wear the vest for 30 minutes and then take a survey assessing it's comfort level. To pass the test at least 8 of our 10 participants needed to say they could wear the vest for an hour or more. We had 11 individuals wear it and they all felt that it was comfortable enough to do so.

The next test performed was to ensure the sounds were being played accurately from the speakers through the fake skin. We ran a two part test where the participants, who were Madison students found in the engineering building, listened to two different heart sounds from the speaker, then one of the two sounds would be played again. To be a successful trial, the participant would have to identify the sound correctly. We tried this test without any fake skin covering the speaker and then again with the fake skin covering it. Initially we had the speakers attached to the vest and it was extremely difficult to hear so we switched to attaching the speakers straight to the skin. Each of our 5 random participants participated in 4 trials both with and without the skin. We then conducted a two proportion z-test to compare the speaker quality with and without the skin. Our null hypothesis was that there is no difference. Upon statistical analysis, at a significance level of 0.05, we found that the difference in our two proportions was not significant. In the future we would like to rerun this test with medical students to make sure there is not a significant difference for those with more knowledge on the sounds.

The final test that we plan to perform pertains to the ease of use of our product. This test is critical as it will test the ability to manipulate and interact with the vest while a simulation is in progress. Through our meeting with the current technology expert in the SimLab at UW hospital, the ease of use is what differentiates a good simulator from a bad one. The instructor, or controller, must have been able to change the sounds coming from each speaker to respond to an intervention applied during the scenario. The ability to manipulate a slideshow with different conditions has been accomplished and future plans involve testing the database with experts. Ten test subjects will briefed on the interface prior to the test. The average time that it takes for an individual to apply the short intervention should be less than 1 minute.

Person (average, our group and found in discovery building)	Sound 1	Sound 2	Sound played	Distinguished?
1	Heart opening snap	Heart pansystolic murmur	Heart pansystolic	Yes
1	Heart diastolic rumble	Heart early systolic murmur	Heart early systolic murmur	Yes
1	Heart - S3	Heart - S4	Heart - S3	Yes
1	Lung - normal vesicular	Lung - pleural friction	Lung - pleural fiction	Yes (with difficulty)
2	Heart opening snap	Heart pansystolic murmur	Heart pansystolic	Yes
2	Heart diastolic rumble	Heart early systolic murmur	Heart early systolic murmur	Yes
2	Heart - S3	Heart - S4	Heart - S3	Yes
2	Lung - normal vesicular	Lung - pleural friction	Lung - pleural fiction	No
3	Heart opening snap	Heart pansystolic murmur	Heart pansystolic	Yes
3	Heart diastolic rumble	Heart early systolic murmur	Heart early systolic murmur	Yes
3	Heart - S3	Heart - S4	Heart - S3	No

Figure 5. Data for Bluetooth Speaker Test without Fake Silicone Skin

Person (average, our group and found in discovery building)	Sound 1	Sound 2	Sound played	Distinguished?
1	Heart opening snap	Heart pansystolic murmur	Heart pansystolic	Yes (much quieter)
1	Heart diastolic rumble	Heart early systolic murmur	Heart early systolic murmur	Yes (with a question mark)
1	Heart - S3	Heart - S4	Heart - S3	Yes
1	Lung - normal vesicular	Lung - pleural friction	Lung - pleural fiction	Yes
2	Heart opening snap	Heart pansystolic murmur	Heart pansystolic	Yes
2	Heart diastolic rumble	Heart early systolic murmur	Heart early systolic murmur	Yes
2	Heart - S3	Heart - S4	Heart - S3	No
2	Lung - normal vesicular	Lung - pleural friction	Lung - pleural fiction	No
3	Heart opening snap	Heart pansystolic murmur	Heart pansystolic	Yes
3	Heart diastolic rumble	Heart early systolic murmur	Heart early systolic murmur	Yes
3	Heart - S3	Heart - S4	Heart - S3	No
3	Lung - normal vesicular	Lung - pleural friction	Lung - pleural fiction	Yes
4	Heart opening snap	Heart pansystolic murmur	Heart pansystolic	No
4	Heart diastolic rumble	Heart early systolic murmur	Heart early systolic murmur	No

Figure 6. Data for Bluetooth Speaker Test with Fake Silicone Skin

Figure 7. Speaker Functionality Pre-Testing

Figure 8. Testing of bluetooth speakers by simulating heart and lung sounds

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Discussion

Bluetooth Speakers

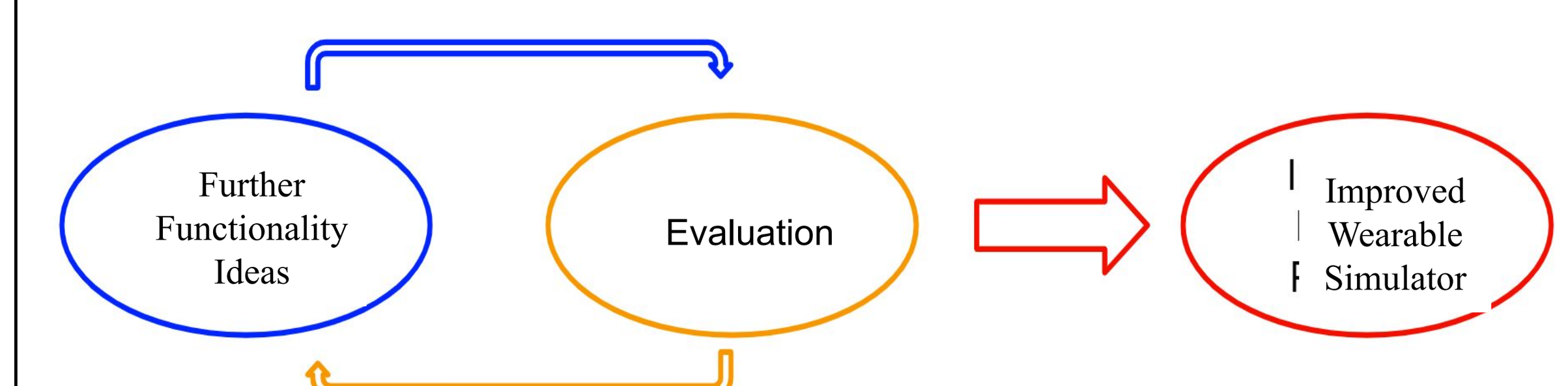
- Upon successful completion of speaker functionality testing, experimental data and statistical analysis suggested that there was no statistical difference between displaying heart and lung sounds without silicone skin and with the speakers behind silicone skin.
- Two proportion t-test yielded a **p-value of 0.05** which is right on the borderline of the team's chosen value of significance.
- The close p-value to the 0.05 benchmark indicates that listening to the playing speakers through the fake skin is evidently not the same as trying to perceive them without the silicone skin, but still gave the team clear information that the skin does not completely impede adequate display of the sounds and closely resembles how the sounds are dimmer when performing auscultation of a patient.
- The results suggest that the speakers can be heard through the silicone skin utilizing a stethoscope as clearly as performing the same action without silicone skin.
- Interpretation of the analysis gave the team clear evidence that the bluetooth speakers will be clearly perceived during an actual training simulation and different physiological sounds will be able to be identified and distinguished.

Comfortability

- The survey conducted by the team assessing comfortability was answered by several users in order to meet durability and comfortability criteria established by our client
- Based on the survey results received, the vest proved to be comfortable for the wearers and it can be easily worn by an actor for an extended period of time during simulation training.
- The survey also suggested that the vest can be worn without damaging the interior electrical components and preserving the structural integrity of the wearable simulator

Future Work

- Future work consists of improving the functionality of the wearable simulator and adding on more components to it in order to fully enhance the realism of the prototype
- More testing shall be done in order to better assess potential problems in our final design and improving it in the future.
- The team plans to team up with the SimMan simulation center to retrieve preliminary information from simulation training at the UW School of Medicine and Public Health and introduce its use to other clinics for primary care.



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