A Deep Learning Approach for AR-based Adaptive Simulation using Wearables

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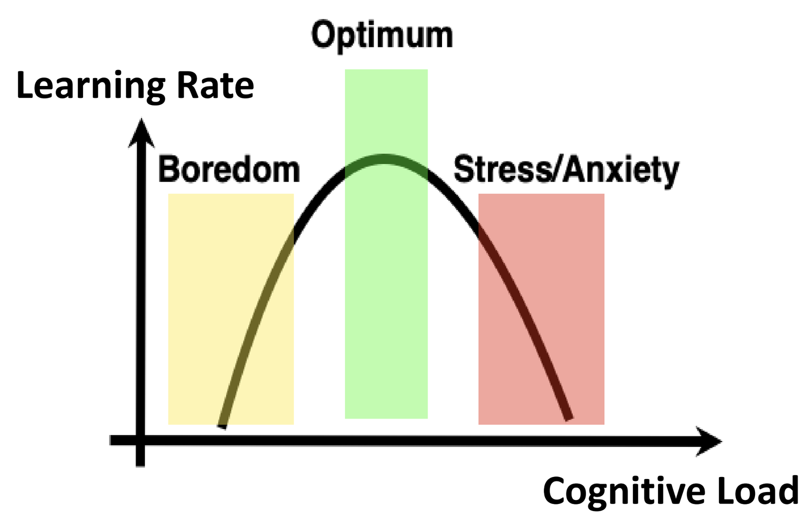
Abstract

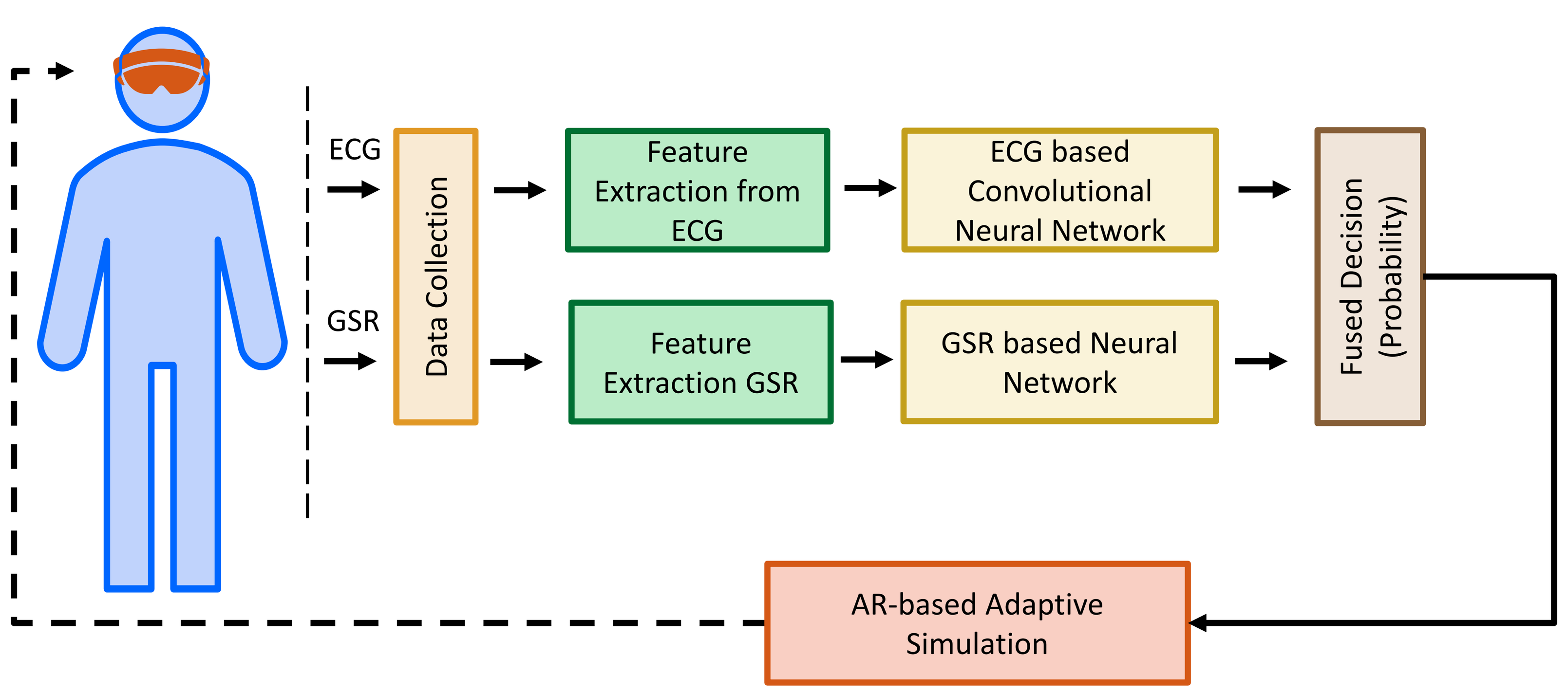
Simulations enable a risk-free way for healthcare practitioners to learn and enhance their skills. Such simulations should be tailored to the needs of the individual learners. However, most current simulations do not consider the learner's existing skills, expertise, and ability to handle cognitive load. We propose an end-to-end framework for trauma simulation that actively classifies participant's cognitive load and level of expertise and dynamically modulates the complexity of a simulation by altering symptom severity of a patient using augmented reality (AR) to ensure an optimum amount of cognitive load is maintained. A deep learning approach was taken to utilize electrocardiogram (ECG) and galvanic skin response (GSR) collected using wearable devices. The model was developed to classify high vs low cognitive load, as well as level of expertise, and validated using "leave one out" scheme. Finally, the intelligent dynamically adaptive AR simulation was successfully tested in real time on two participants of each class.

Motivation



- Many learning systems are ***one size fits all*** regarding levels of ***expertise.***
- The development of expertise is characterized by the ability to execute increasingly complex tasks with ***lowered cognitive load.***
- To be effective, simulations should ***match complexity*** with the cognitive abilities of the learner.
- ***Goal***: To develop a learning system that dynamically adjusts complexity to ***match learner expertise and cognitive capacity.***

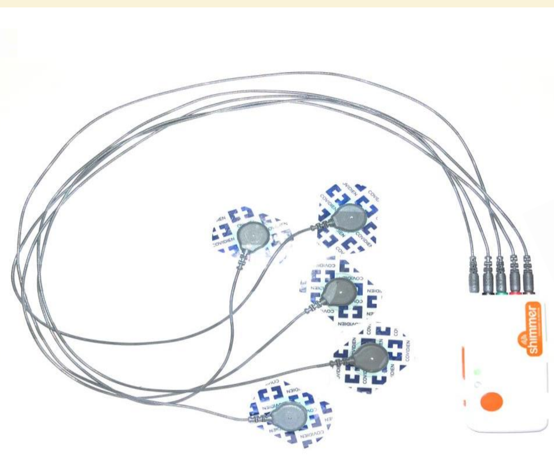
Proposed Dynamic Simulation Framework



Data Collection

- Expert participants (Experienced in emergency medicine)
- Novice participants (Queen's 4th year medical students)

Microsoft HoloLens

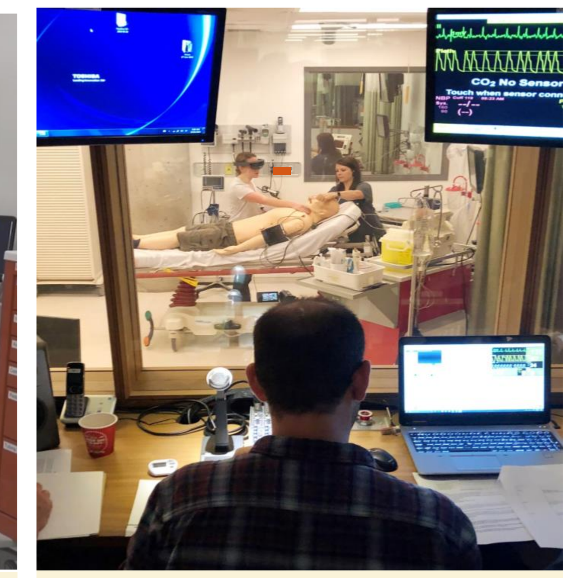


ECG Shimmer Sensor

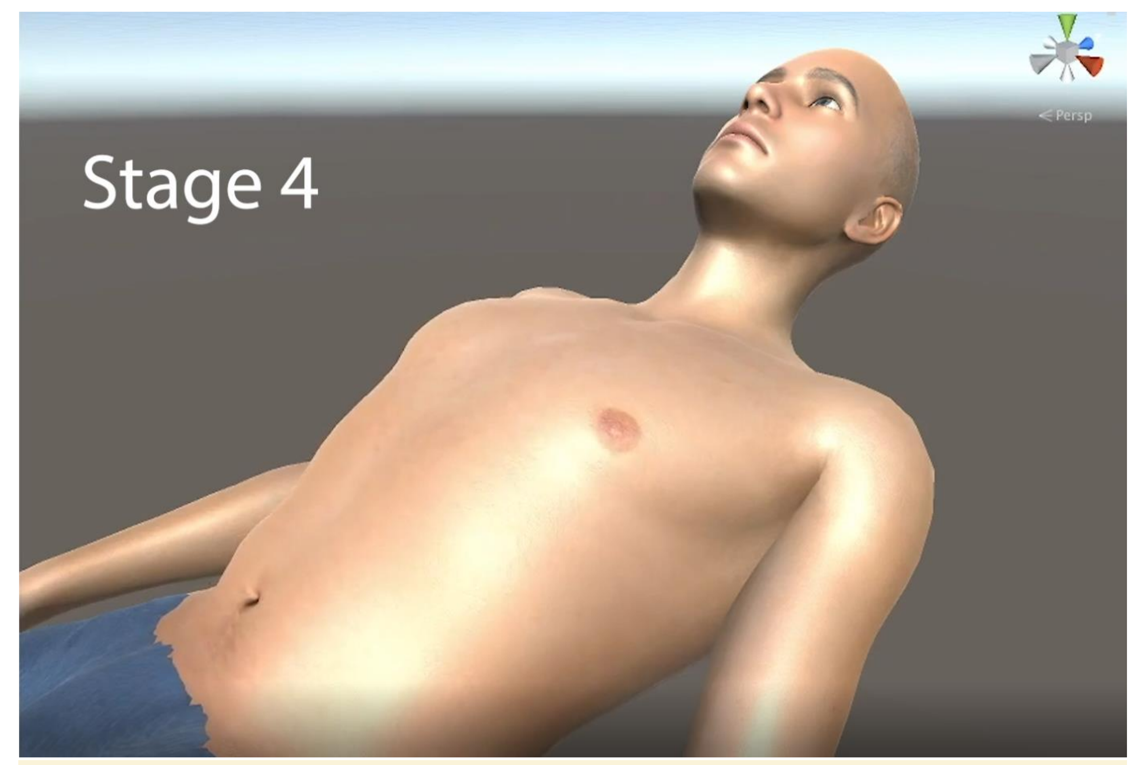
GSR Shimmer Sensor

Experiment Setup

View from HoloLens during simulation

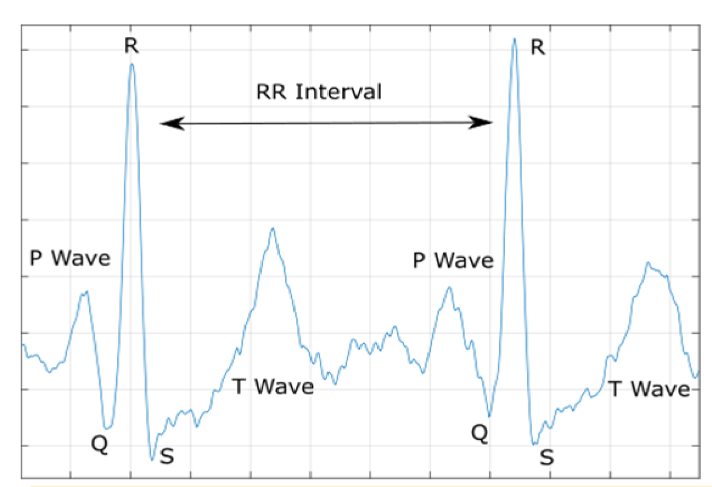


Participants during simulation



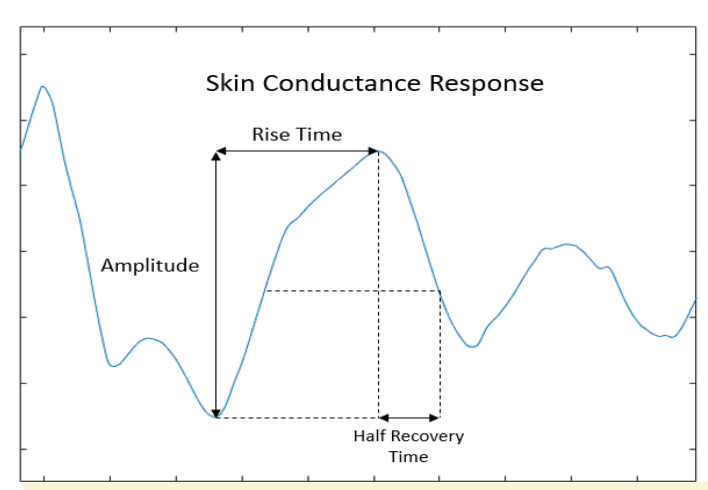
We used an augmented reality overlay on top of a mannequin to change the difficulty of the simulation through patient symptomology

Data Pre-processing & Feature Extraction



Time Domain Features	Frequency Domain Features
RR_{min}	ULF
RR_{max}	VLF
RR_{diff}	LF
RR_{mean}	HF
RR_{SD}	TP
RR_{CV}	LF_{norm}
SDSD	HF_{norm}
NN50	LF/HF
PNN50	LMHF

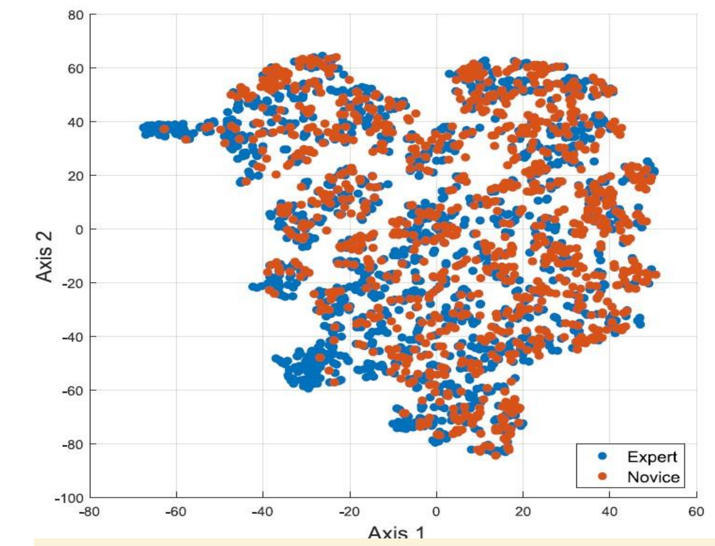
RR peaks for ECG feature extraction

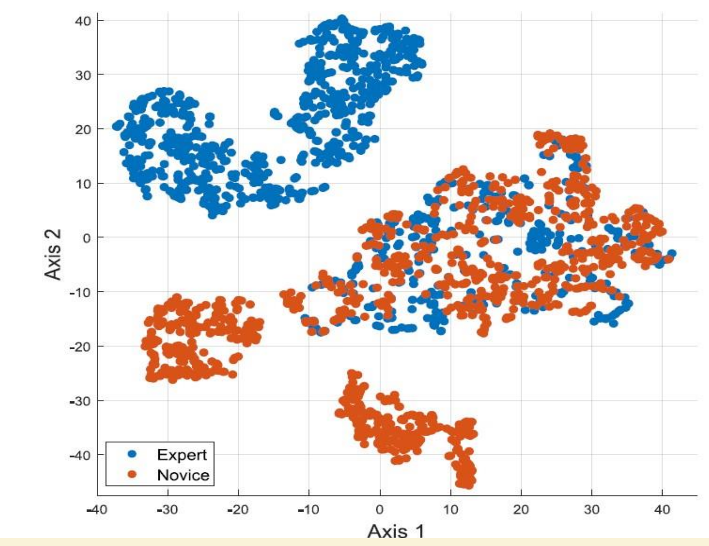


Features
RT
HRT
Amp
Area
Prom
SCL
MAV1Diff SCL
MAV2Diff SCL
BP
PSD

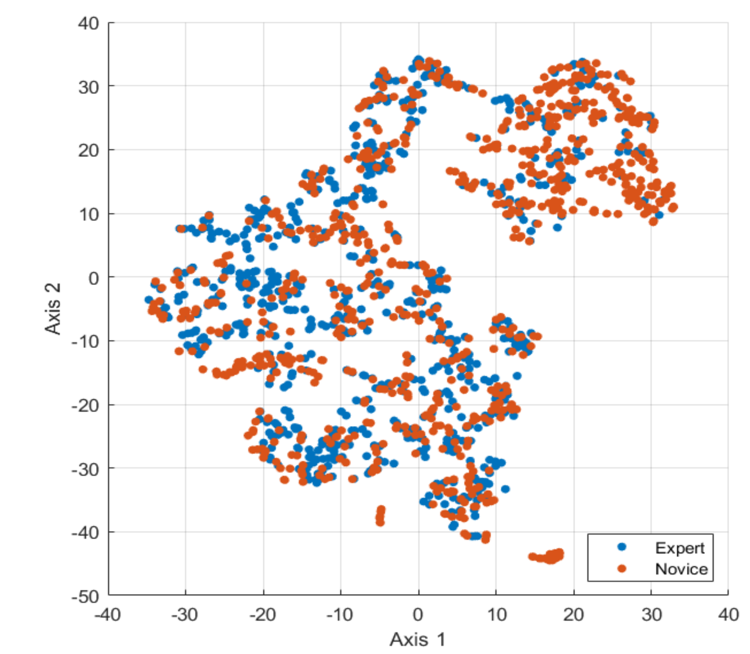
SCR response for GSR feature extraction

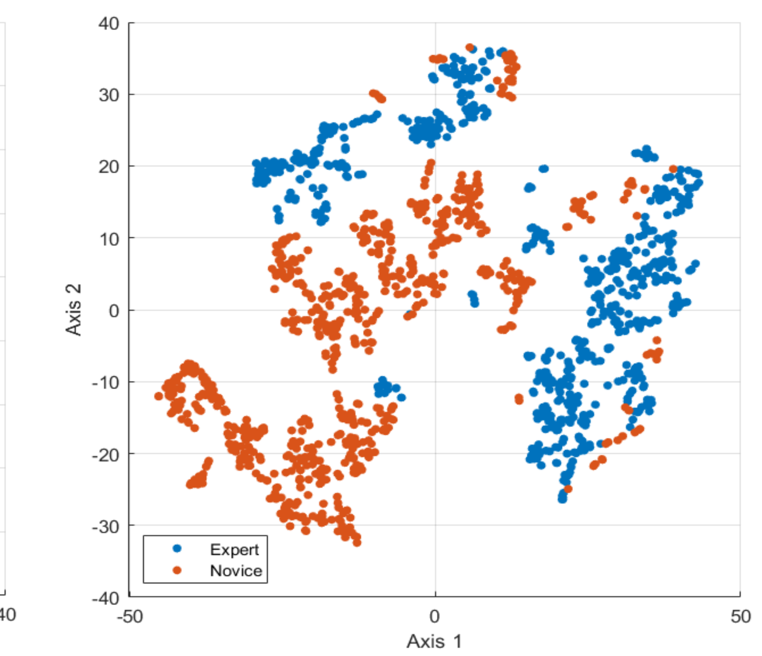
Data Visualization





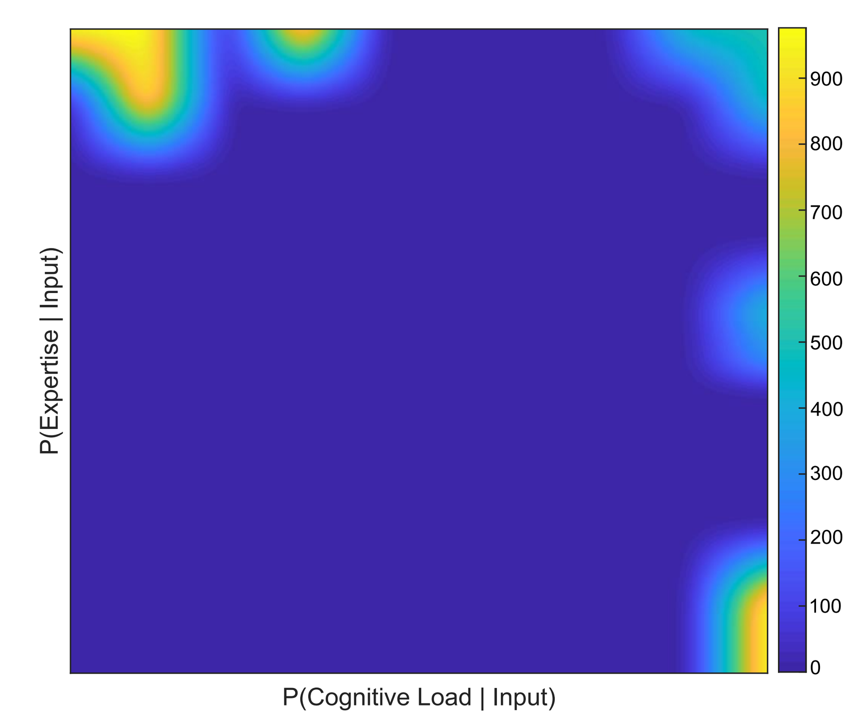
TSNE plot of ECG feature-space without (left) and with (right) baseline correction





TSNE plot of GSR feature-space without (left) and with (right) baseline correction

Result and Analysis



	Expertise	Cognitive Load
Testing (Offline)	91%	74%
Realtime Testing	2 participants of each class were successfully tested to classify level of expertise and cognitive load.	

(Left) Plot of the likelihood for expertise vs cognitive load. The results show an inverse relationship between level of expertise and cognitive load, where the top left corner shows high level of expertise and low cognitive load, and the bottom right corner indicates low expertise and high cognitive load.

Conclusion

We were able to accurately estimate cognitive load and expertise in real-time and use the classifications to alter a simulation with augmented reality to maintain optimal cognitive load.

Publications

- **Conference:** Classification of Expertise and Cognitive Load in Adaptive AR-Based Simulation using Deep Learning, *Affective Computing & Intelligent Interaction (ACII), 2019*
- **Journal:** Toward Dynamically Adaptive Simulation: Multimodal Classification of User Expertise using Wearable Devices, *Sensors 2019, 19, 4270*

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