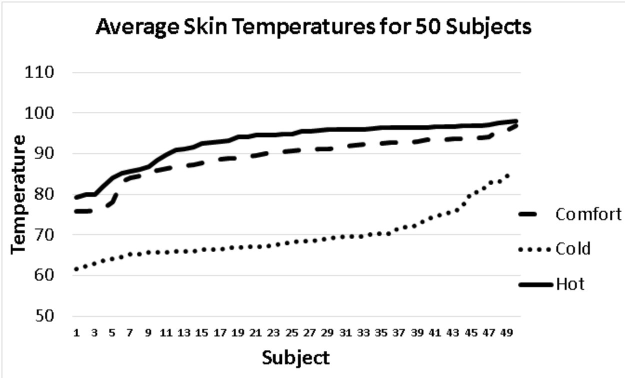

Figure 2: Sorted average temperatures of the 50 subjects through the comfort, cold discomfort, and hot discomfort stages.

from the cold discomfort state to the hot discomfort state. This also indicates that the human body has faster adaptation to heat.

5. CONCLUSION

In this paper, we presented our approach in automatically detecting the thermal sensation of subjects in an enclosed environment similar to that in vehicles. This is a step toward developing technologies that are capable of providing automated climate control without any explicit input from the users.

We presented a novel dataset collected from 50 subjects as well as an approach that utilized four different physiological sensors to detect thermal discomfort. We analyzed the performance of each of these sensors and found that the skin temperature sensor performed the best followed by a combination of all the sensors. The respiration rate sensor and the skin conductance sensor were not good indicators of the thermal discomfort levels of the subjects. Furthermore, it was also shown that our approach was capable of detecting different levels of cold discomfort and hot discomfort separately.

Interestingly, the cold discomfort was detected more reliably than hot discomfort. This is due in part to the human body's built in thermoregulation mechanisms that, in a cold climate, can lower the skin temperature as needed (to reduce heat loss while deploying vasoconstriction) while it will keep its temperature nearly constant when heated (the body's temperature is controlled through sweating and evaporation when the outside temperature is above 37^o C). It was also observed that it took almost double the time to reaching a certain level of cold discomfort compared to hot discomfort. This could be explained using thermoregulation as well as the first law of Thermodynamics. When the human body is being cooled the energy that needs to be expelled from the body is higher due to the metabolic heat production. When the body is heated the metabolic heat does not need to be expelled. This can indicate that humans adapt thermally to heat faster than cold.

There are three directions in improving this research in the future. First, we expect improvement in performance as we extract additional features from the thermal video recordings of the subjects, and integrate them with the physiological sensors features. Second, more instances are needed in order to train our system on separating different levels of cold discomfort and hot discomfort. Third, additional time needs to be added for the heat discomfort stage in order to have reasonable separation from the comfort level, taking also into consideration that the hot discomfort simulation was conducted right after the cold discomfort.

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