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2016 Purdue Conferences
Compressor Engineering
Refrigeration and Air Conditioning
High Performance Buildings

Sensitivity Analysis For The PMV Thermal Comfort Model and The Use of Wearable Devices to Enhance Its Accuracy

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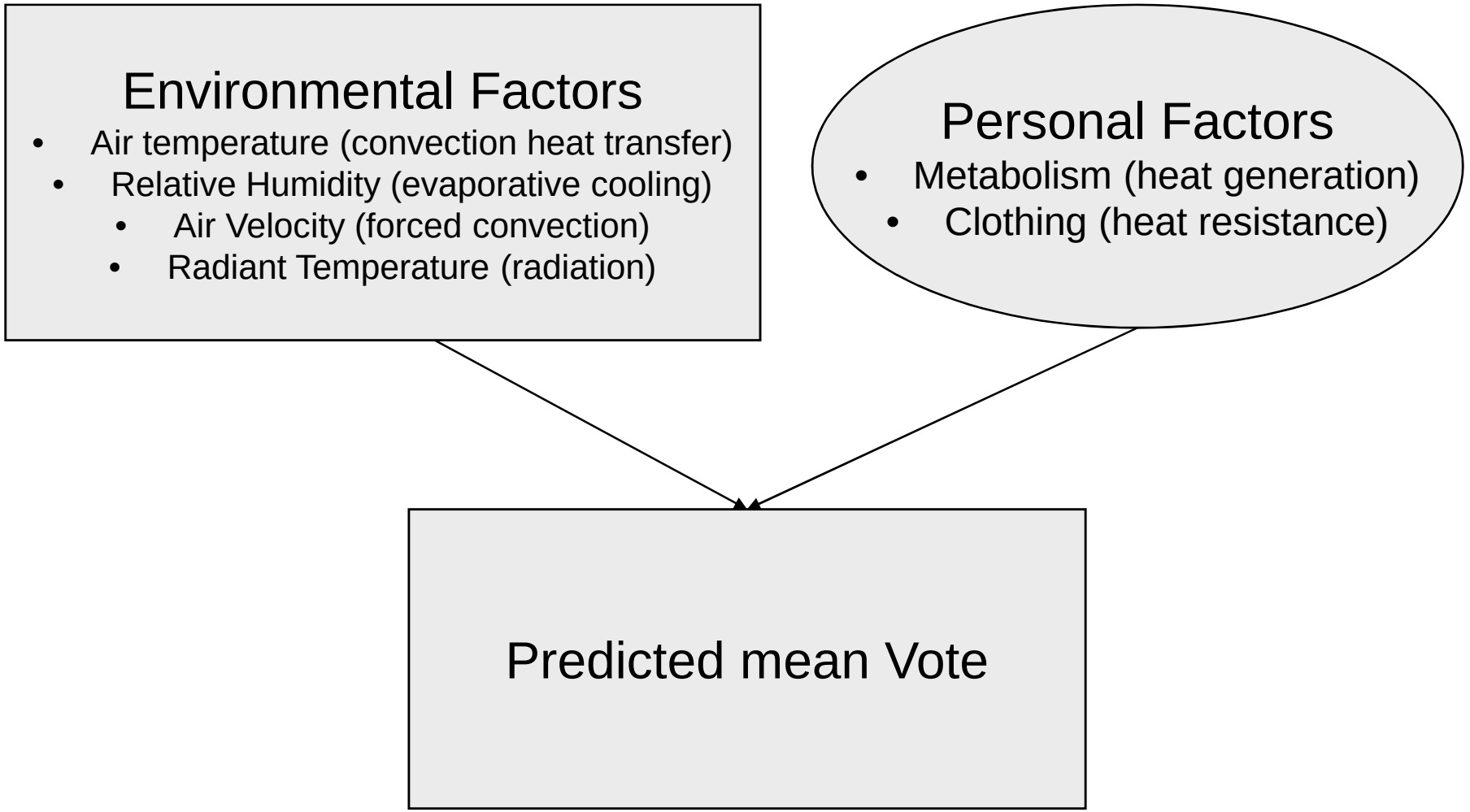
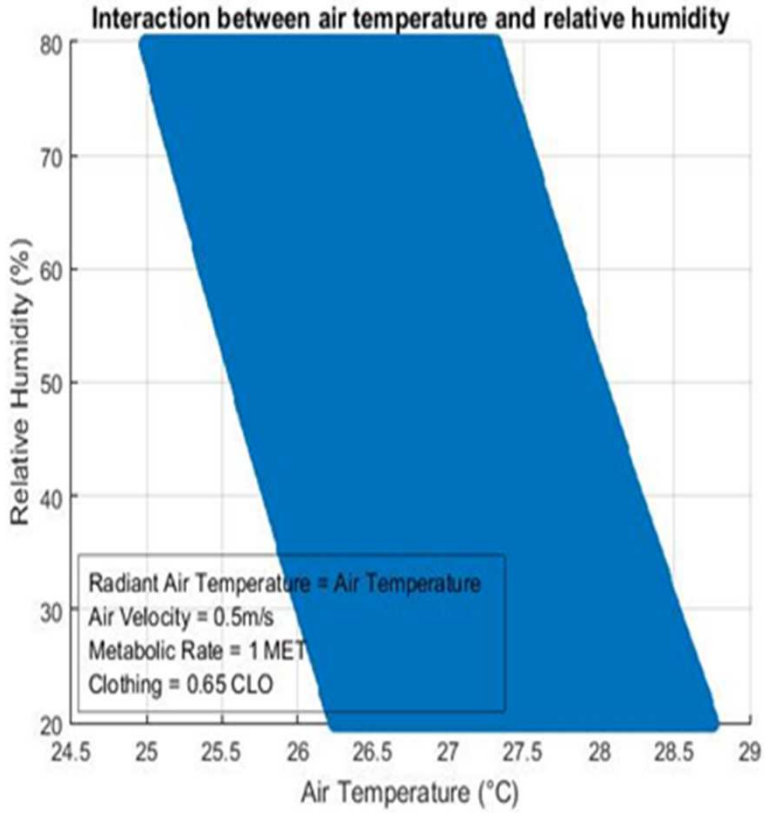
Predicted Mean Vote

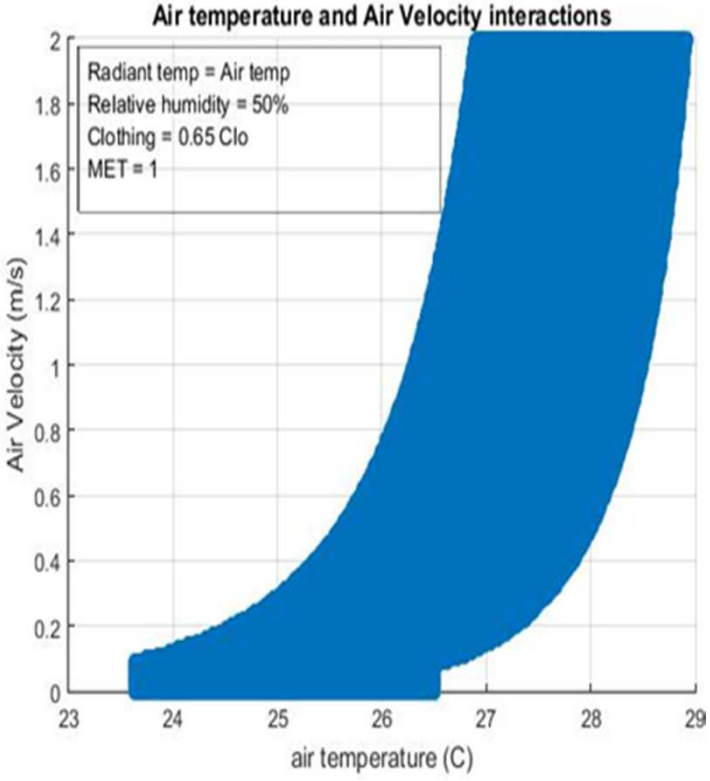


Outlines

- **Environmental Factors Simulation**
- **Personal Factors Simulation**
- **Sensitivity Analysis**
- **Metabolism Estimation**
- **Conclusion**
- **Future Works**

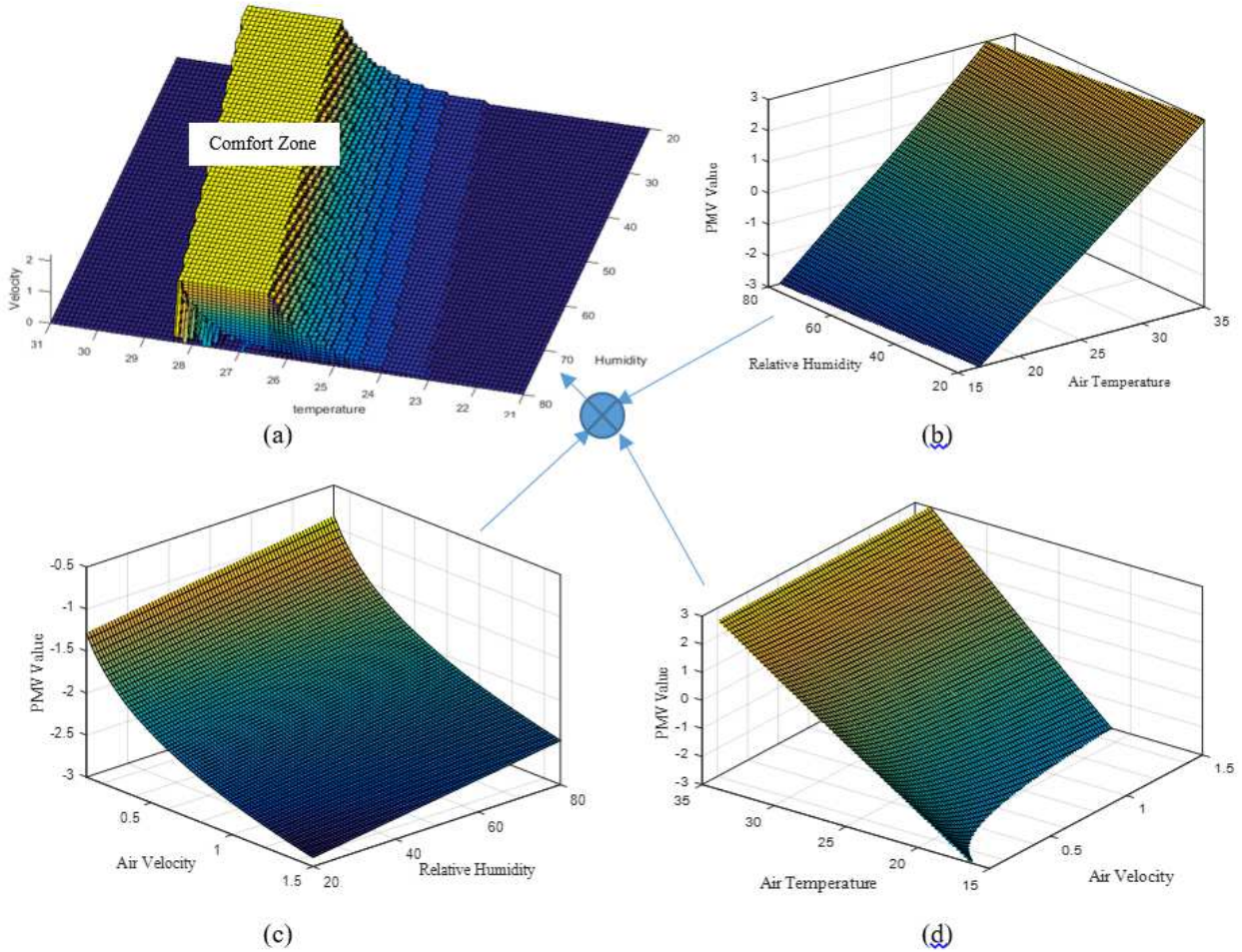
2-D Comfort Zone





Comfort zone is affected by temperature, humidity , and air velocity

Multi Dimensional Comfort Zone



Complete effect of the environmental factors

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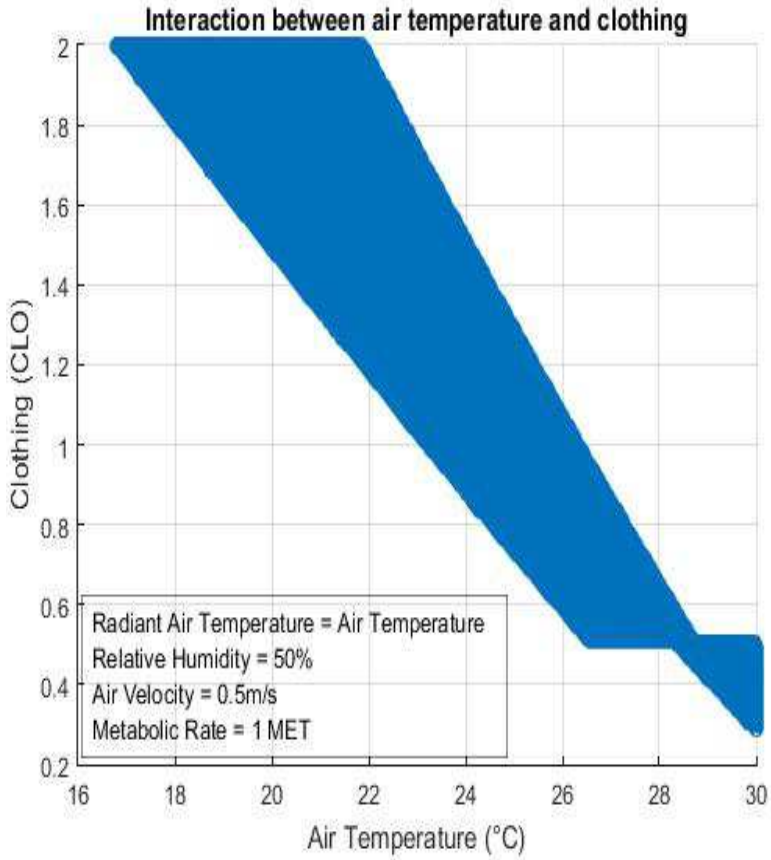
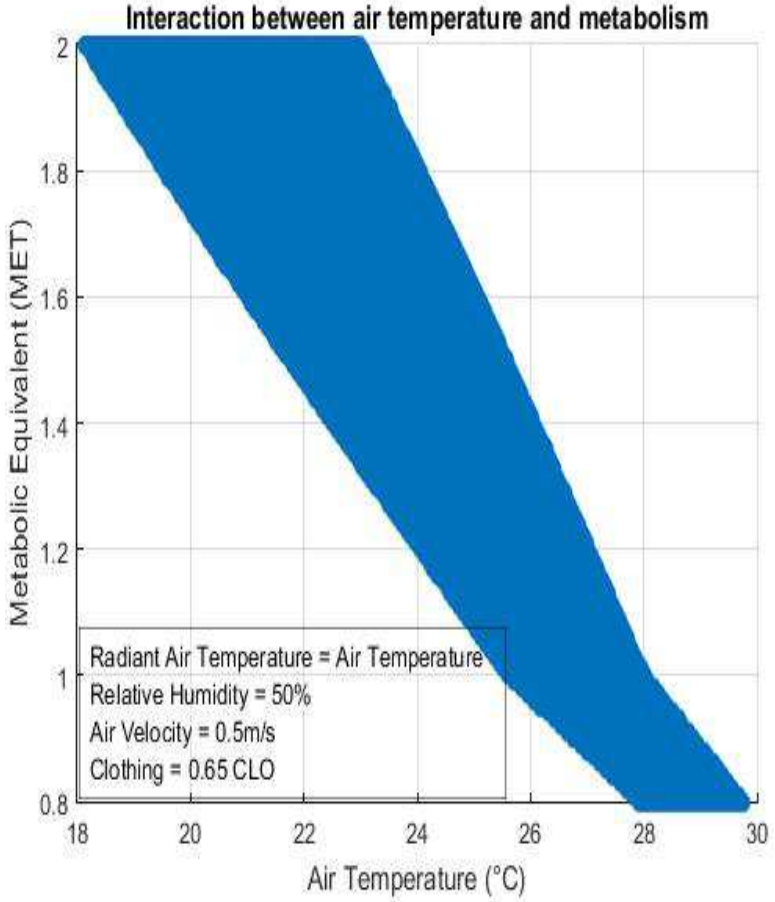
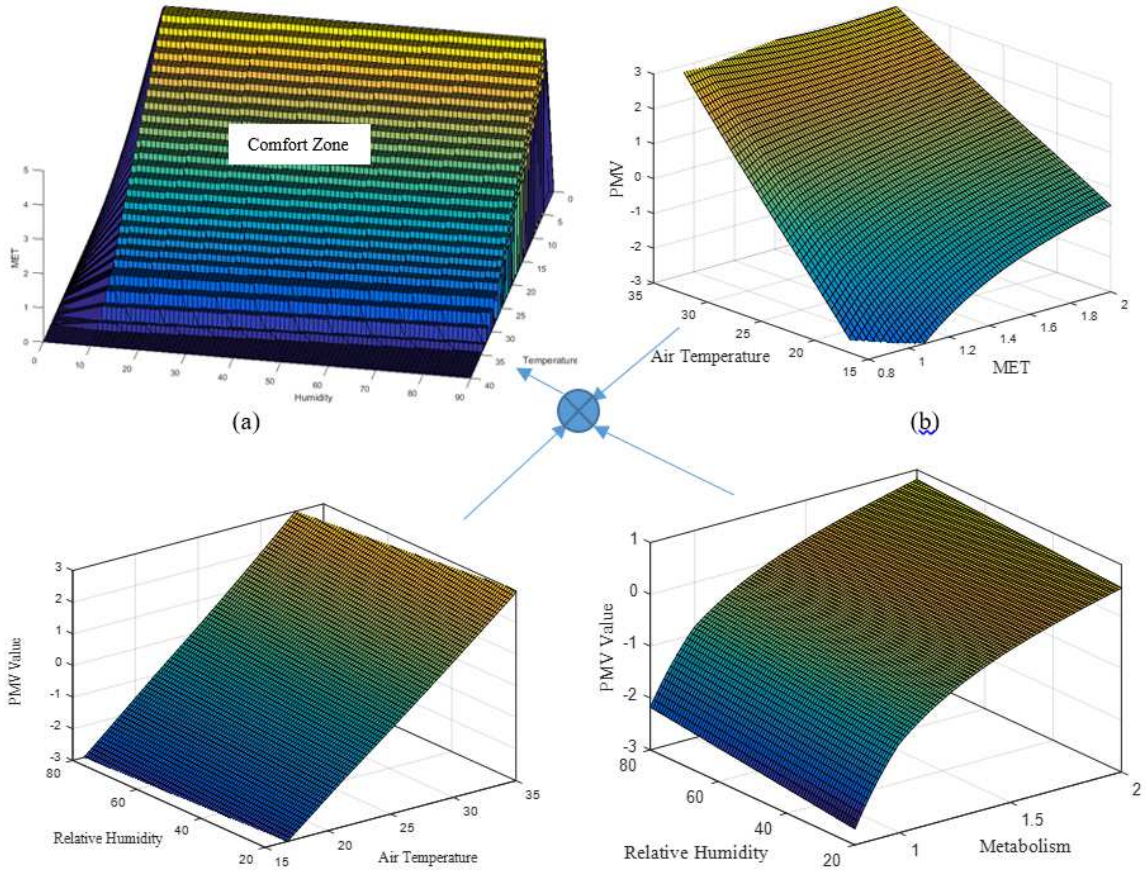
2-D Comfort Zone





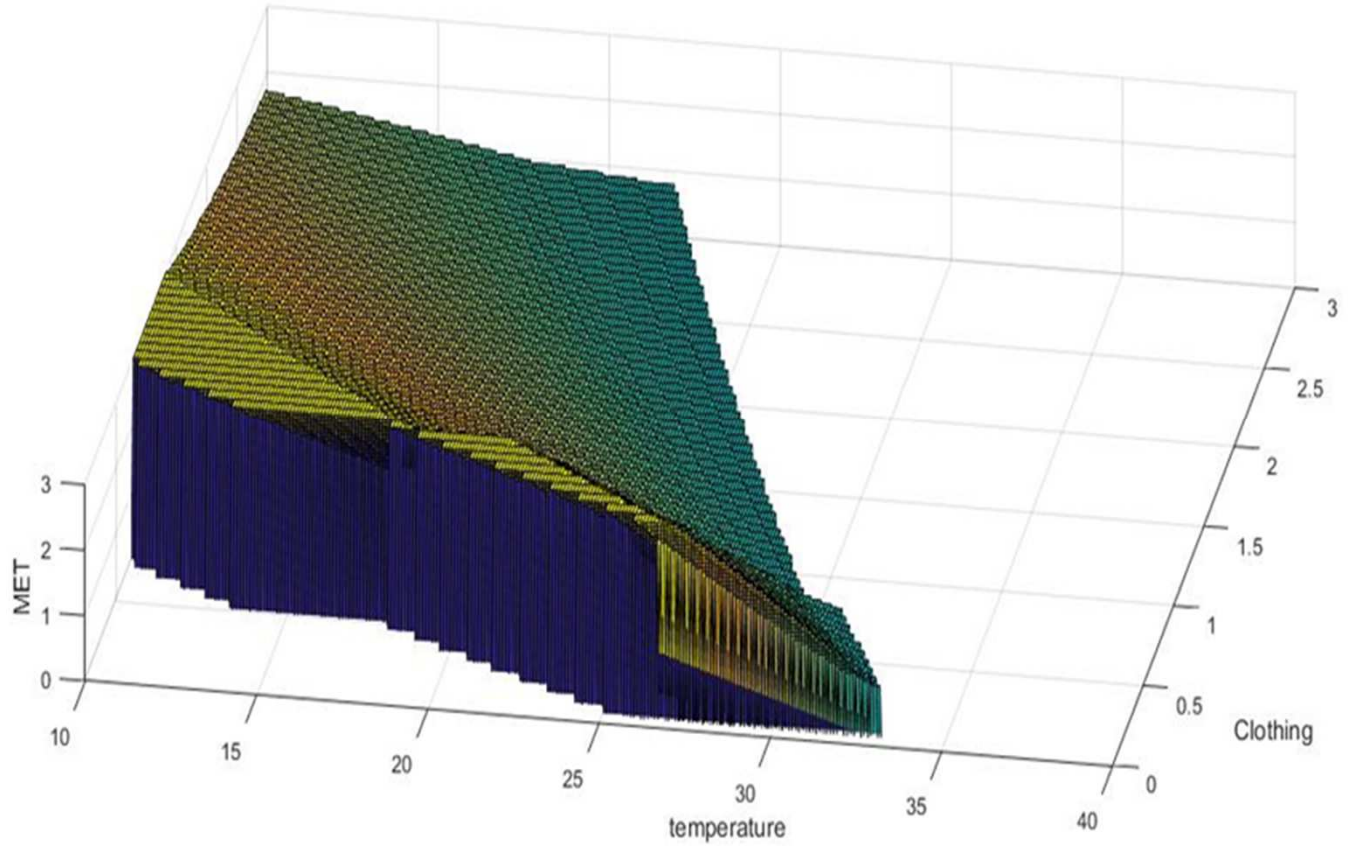
The comfort zone is highly affected by clothing and metabolism in a nonlinear fashion

Multi Dimensional Comfort Zone



Environmental factors and the metabolic rate combined effect

Multi Dimensional Comfort Zone cont.



Factors of highest impact for comfort

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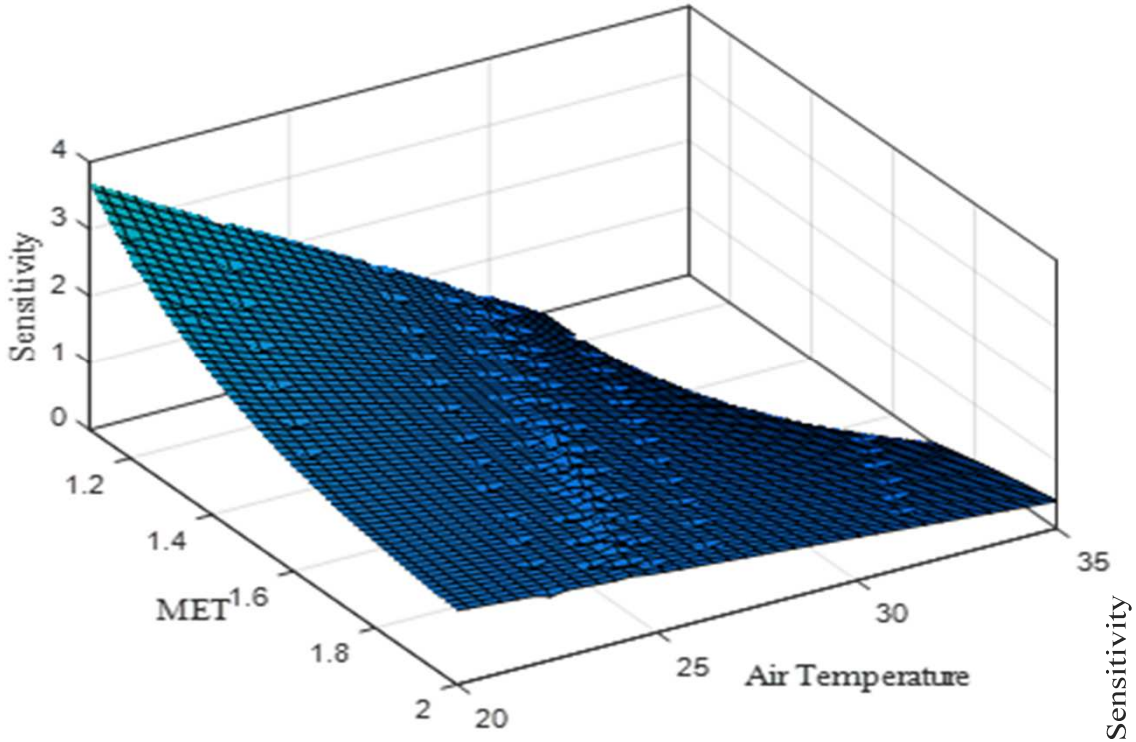
Sensitivity

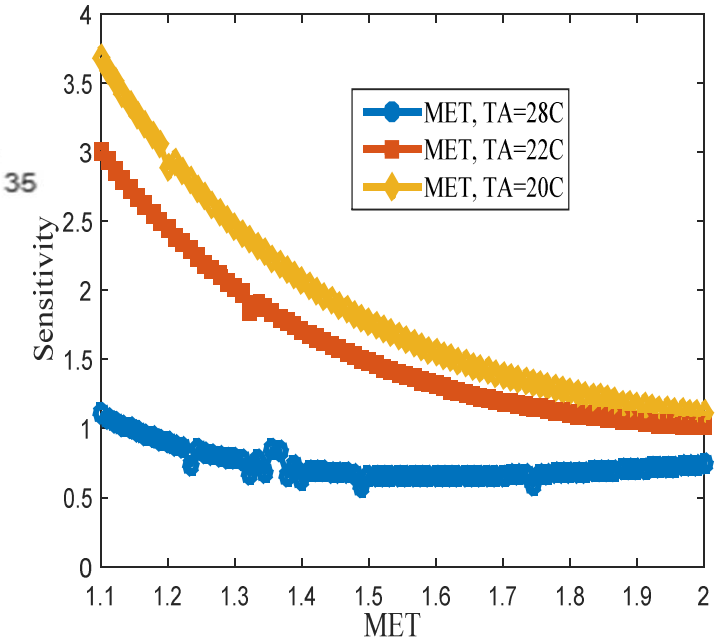
- Comfort graphs show the qualitative sensitivity of comfort zone to different parameters

- Quantitative sensitivity can show the absolute effect of each parameter

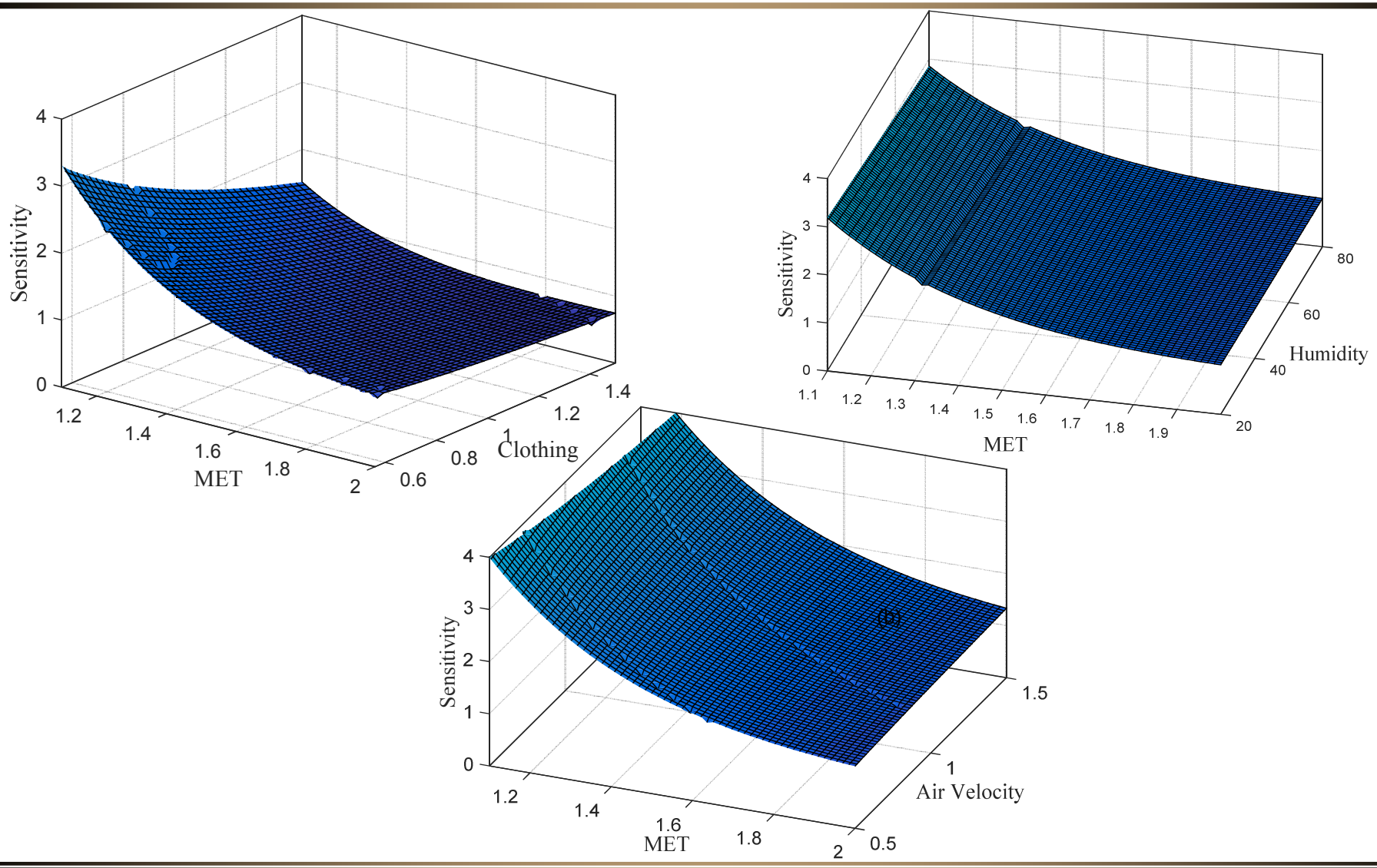
$$S_x[f(x,y,z)] = \frac{\partial f(x,y,z)}{\partial x}$$

Metabolic Rate Sensitivity

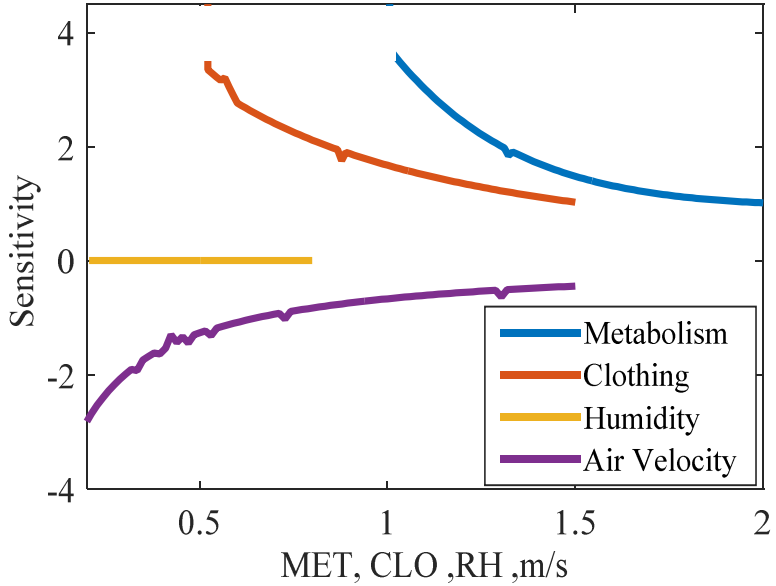


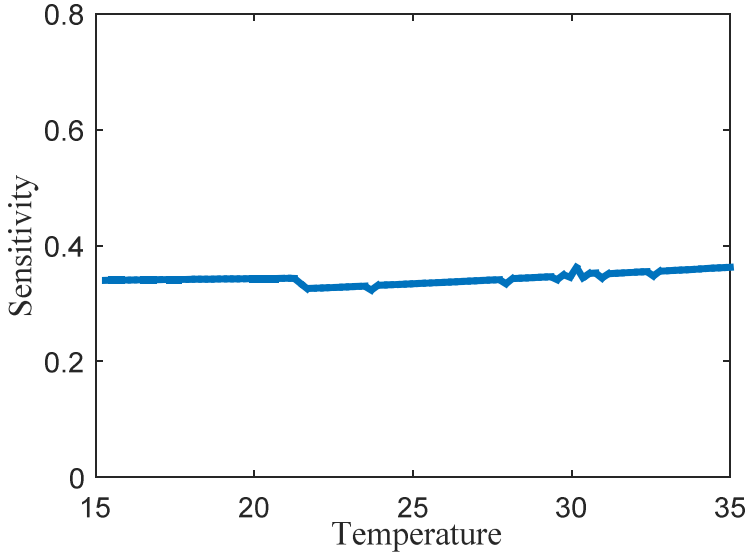


Sensitivity to Other Parameters



Sensitivity Summary





(b)

Parameter		Sensitivity (mean)	Sensitivity (range)
Air temperature (AT)		$S_{AT} \cong .34\ °C^{-1}$	.04
Humidity (RH)		$S_{RH} \cong 0.007\ RH^{-1}$	~0
Clothing (CLO>0.5)		$S_{CLO} = 1.3\ CLO^{-1}$	1.22
Clothing (CLO<0.5)		$S_{CLO} = 5.53\ CLO^{-1}$	2.8
Air Velocity ($AV>0.5$)		$S_{AV} = -.72\ m^{-1}s$	0.87
Air Velocity ($AV<0.5$)		$S_{AV} = -2.2\ m^{-1}s$	2.9
Metabolism ($MET>1$)	T=20°C	$S_{MET} = 2.09\ MET^{-1}$	3.37
	T=22°C	$S_{MET} = 1.6\ MET^{-1}$	2.0
	T=28°C	$S_{MET} = 0.79\ MET^{-1}$	1.25

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Metabolism

- Actual measurement require oxygen and/or bi-products through breathing
- Estimation is possible through smart devices
- Heart rate, pedometers and accelerometers as metabolic rate approximators

Fitbit for MET approximation

- Metabolic equivalent :

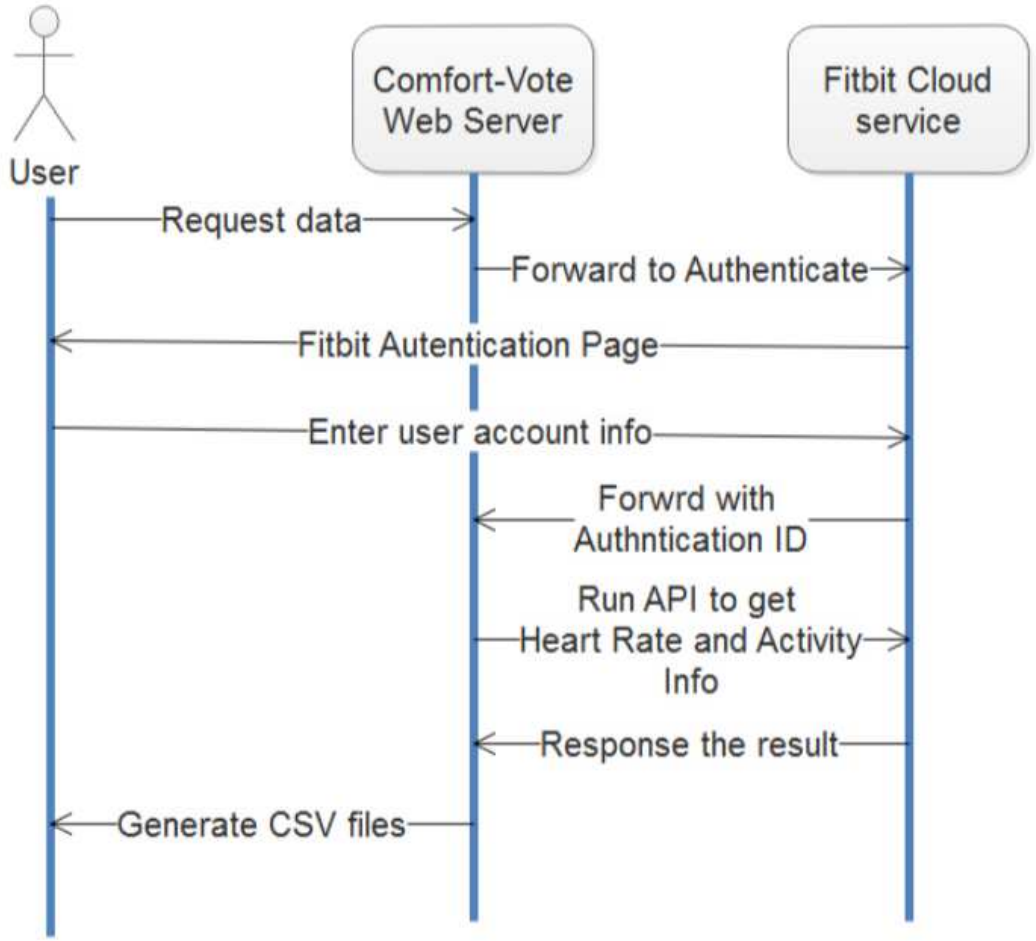
Energy consumed at rest per hour per

Per unit weight

- BMR calculation (Kcal/sec)

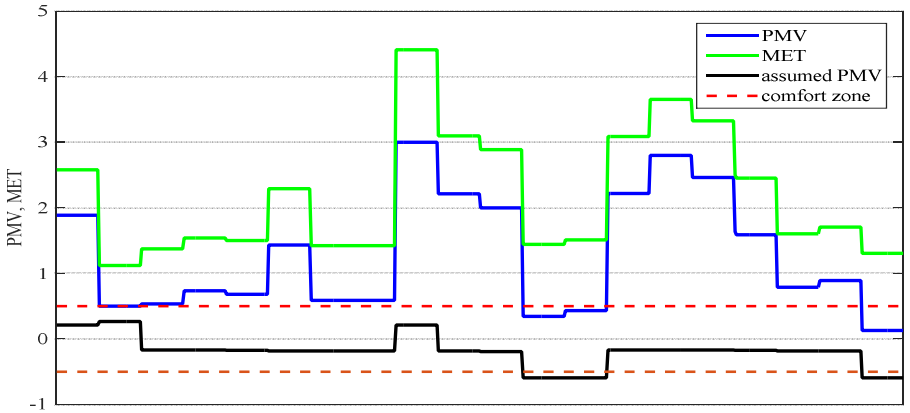
- Estimated Energy Rate EER
- $MET = \frac{EER}{BMR}$

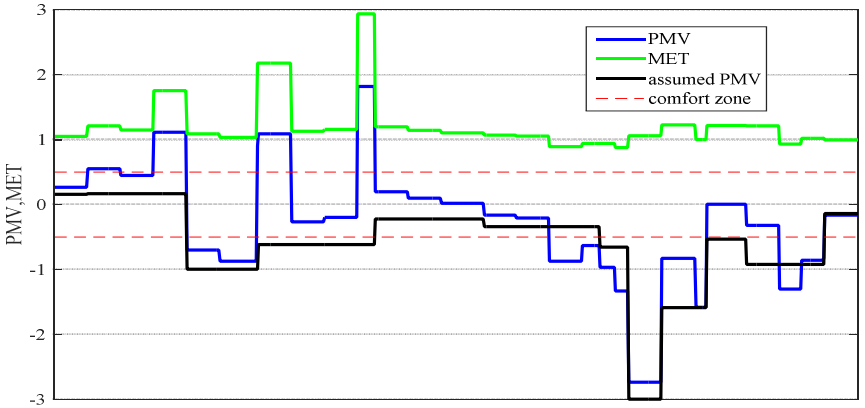
Fitbit data acquisition

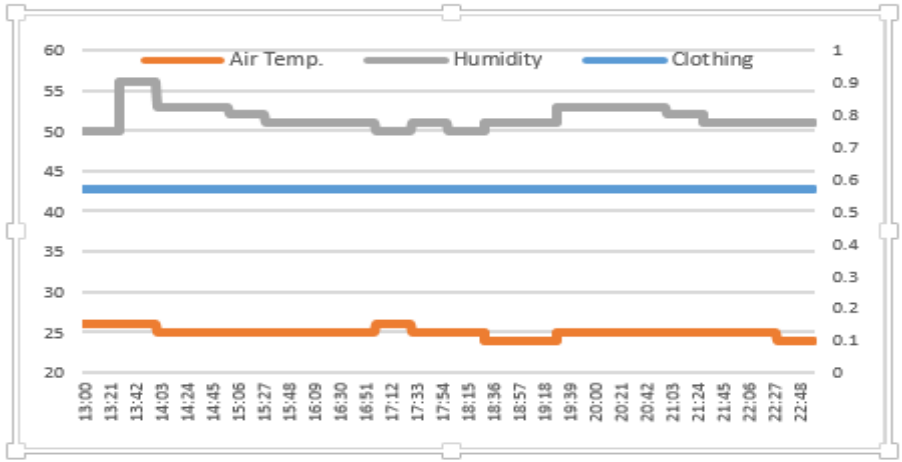


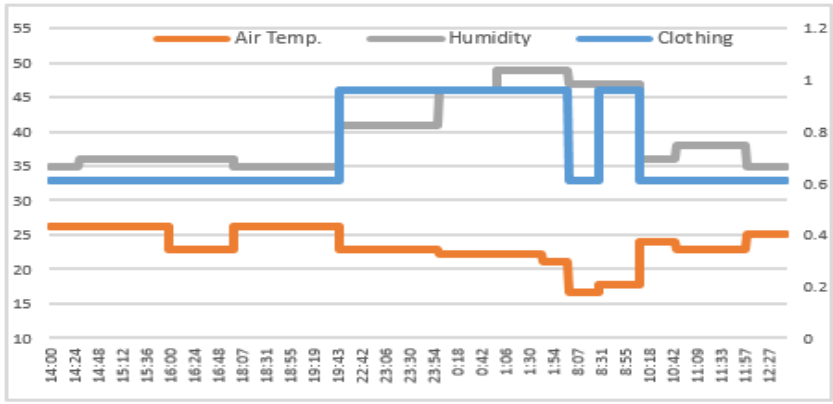
Case Study of FitBit

Two graduate students (22 year-old male and a 35 year-old male)









The values of MET varies throughout the day making the actual comfort value higher than expected

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Conclusion

- It is possible to relate back to an already-made comfort surface to solve the inverse model
- The effect of Personal factors must not be underestimated
- The use of wearable devices improves the comfort model and a feedback program can help boost the accuracy

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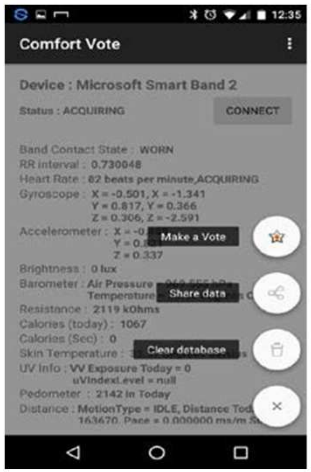
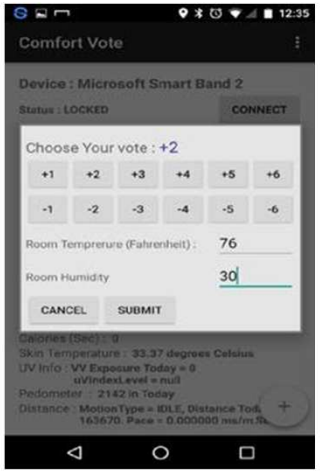
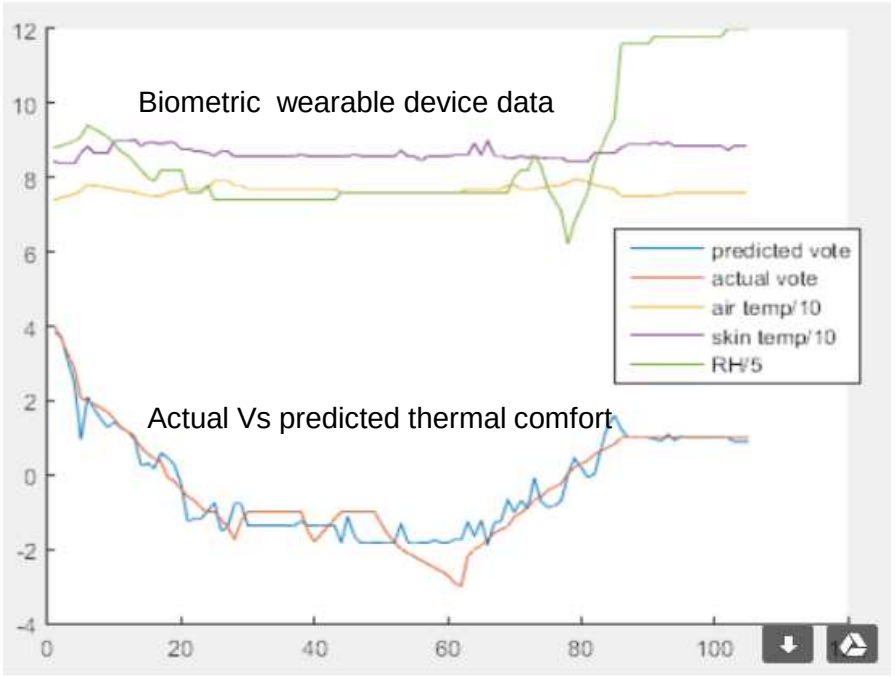
Future Works
Personalized comfort model

Wearable device biometric data can be used to inform individual comfort level







Thank you !