

# Behavioural analysis to changes in environmental temperature— a step towards the personalization of general thermal comfort models

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## Introduction and objectives

Thermal comfort is an area of interest, and it is related to a range of fields from human well-being to indoor environmental climate control. Modelling and predicting thermal comfort is highly difficult due to numerous environmental and personal factors.

The state-of-the-art in the field is the development of more complex adaptive thermal comfort models taking into account more parameters and the individual responses to an environment (behavioural and physiological), such that they can predict more accurately the thermal sensation and thermal comfort of a specific person.

The aim of the project is to study the behavioural response of individuals (specifically the use of a table fan) and its relation with the skin (via infrared images) and core temperatures (from forehead temperature). The relation between the recorded parameters was subsequently analysed, informing the development of the new generation of adaptive thermal comfort models.

## Methodology

### Experimental set up

- The experiment was conducted in a climate chamber.
- 11 volunteers were subjected to a range of temperatures for 2 hours while a thermal camera was used to monitor their forehead temperature.
- They were provided with a fan to use at will.
- Sensors monitored humidity and room temperature as well as fan usage.
- Every ten minutes, volunteers completed a questionnaire as to their comfort and sensation in the temperature and core temperature was recorded.
- All data collected is to be used to note and observe trends and usage of thermal cameras for an adaptive thermal comfort system.
- This study has been approved by the UCL ethics committee, code 13831/001.



Fig.1 Set up of the experiment in the climate chamber.

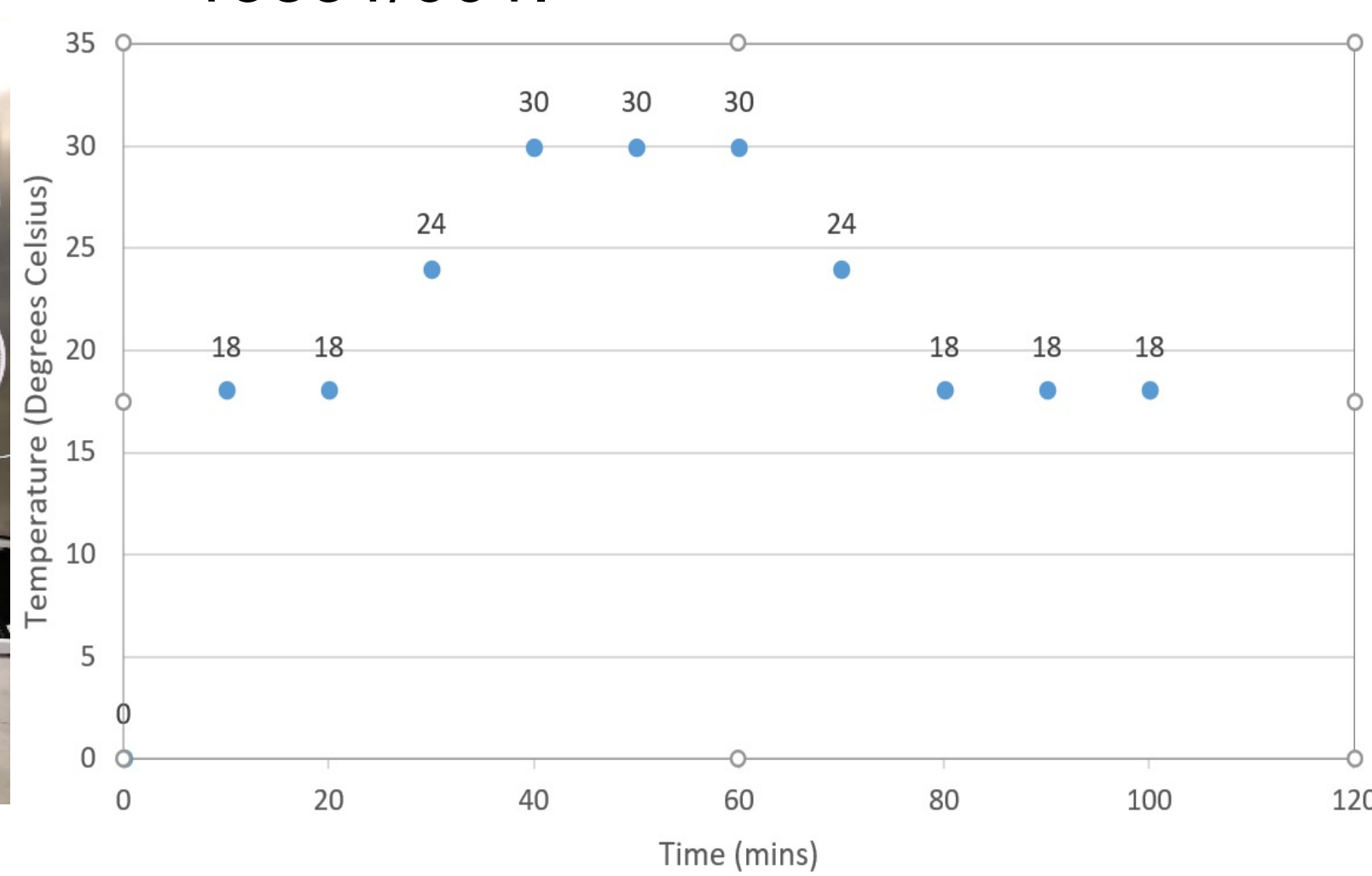


Fig.2 Temperature profile of the experiment.

### Analysis

- The forehead temperature profile was extracted from the infrared images (e.g. fig 3) using automated or manual forehead position selection, and the average forehead temperature used for further analysis.
- The images were screened into 3 quality types (see examples in Fig 4-6), and suitable ones processed further alongside with other factors. (Fig. 7-10)



Fig 3 Example of thermal image with colours used to represent temperature of pixels.



Fig. 4 Example of 'Higher quality image' (Pixels representing a good spread of the forehead)



Fig. 5 Example of 'lower quality image, (Pixels representing a poor spread of the forehead)



Fig. 6 Example of 'unusable image', (Pixels representing a misleading spread of the forehead as the fingers are in the way)

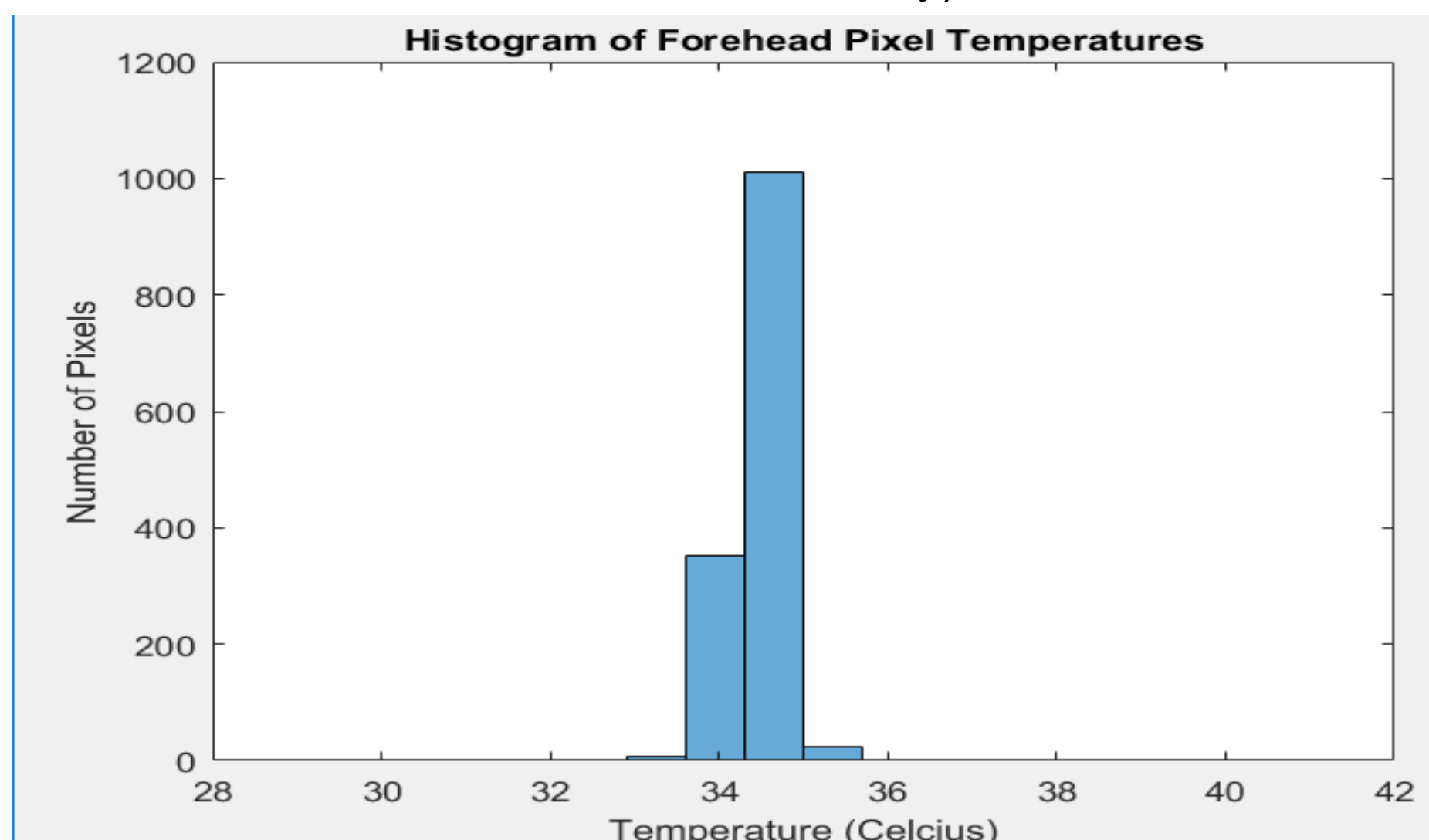
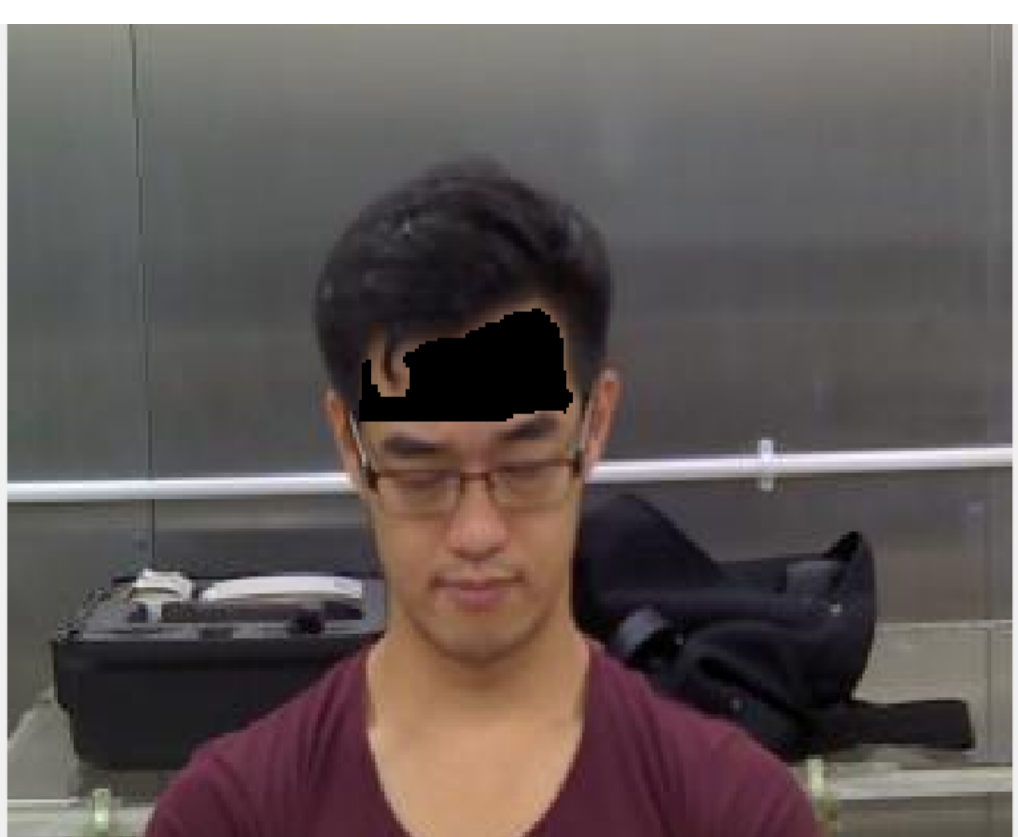


Fig.7 Example of (a) forehead detection (b) and histogram of pixels' temperature, displaying fairly typical distribution with the majority of pixels contained in a few of the 20 histogram bins.

## Results

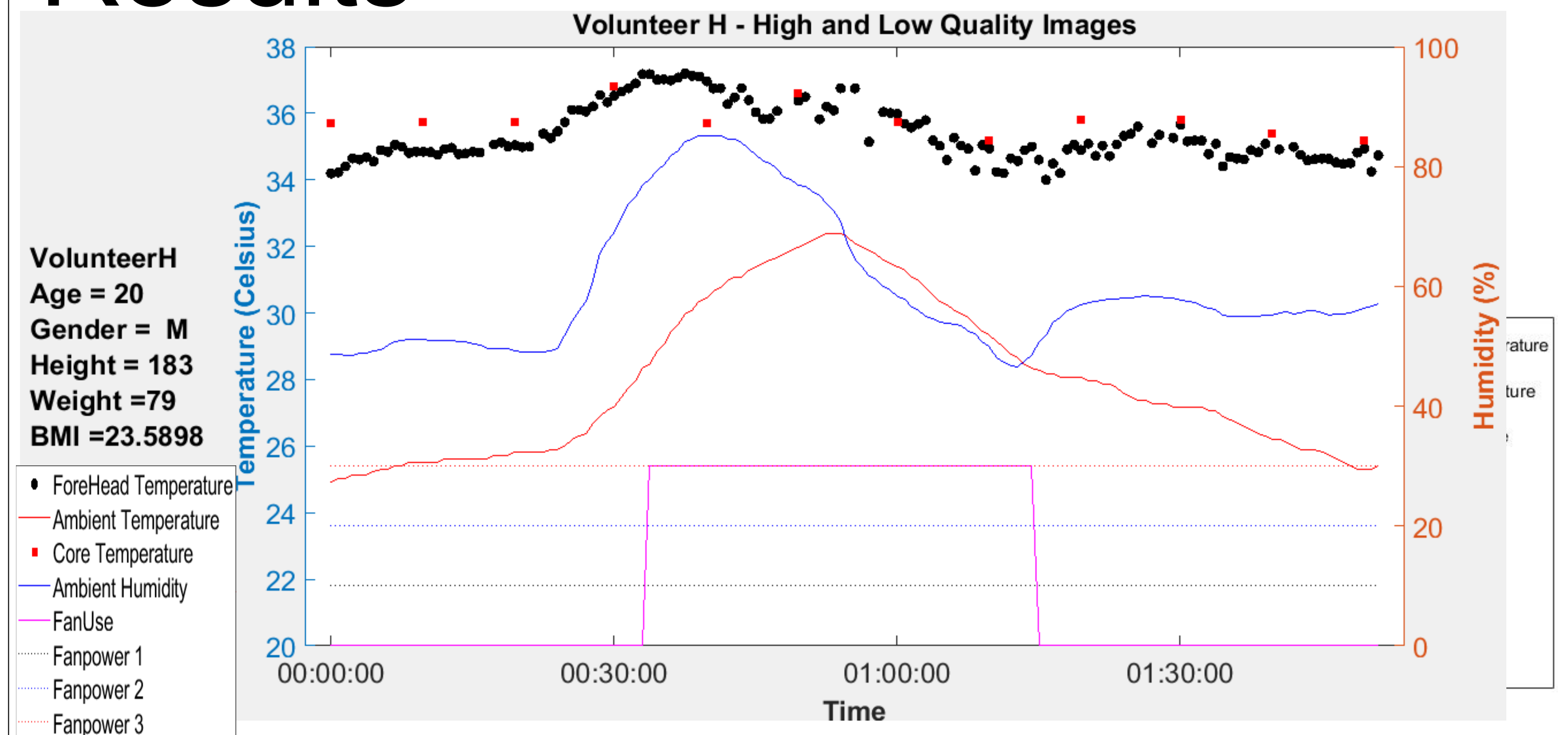


Fig.8 Example of graph representing one volunteer. Shown are the ambient temperature, humidity, forehead temperature, core temperature and fan usage all over time.

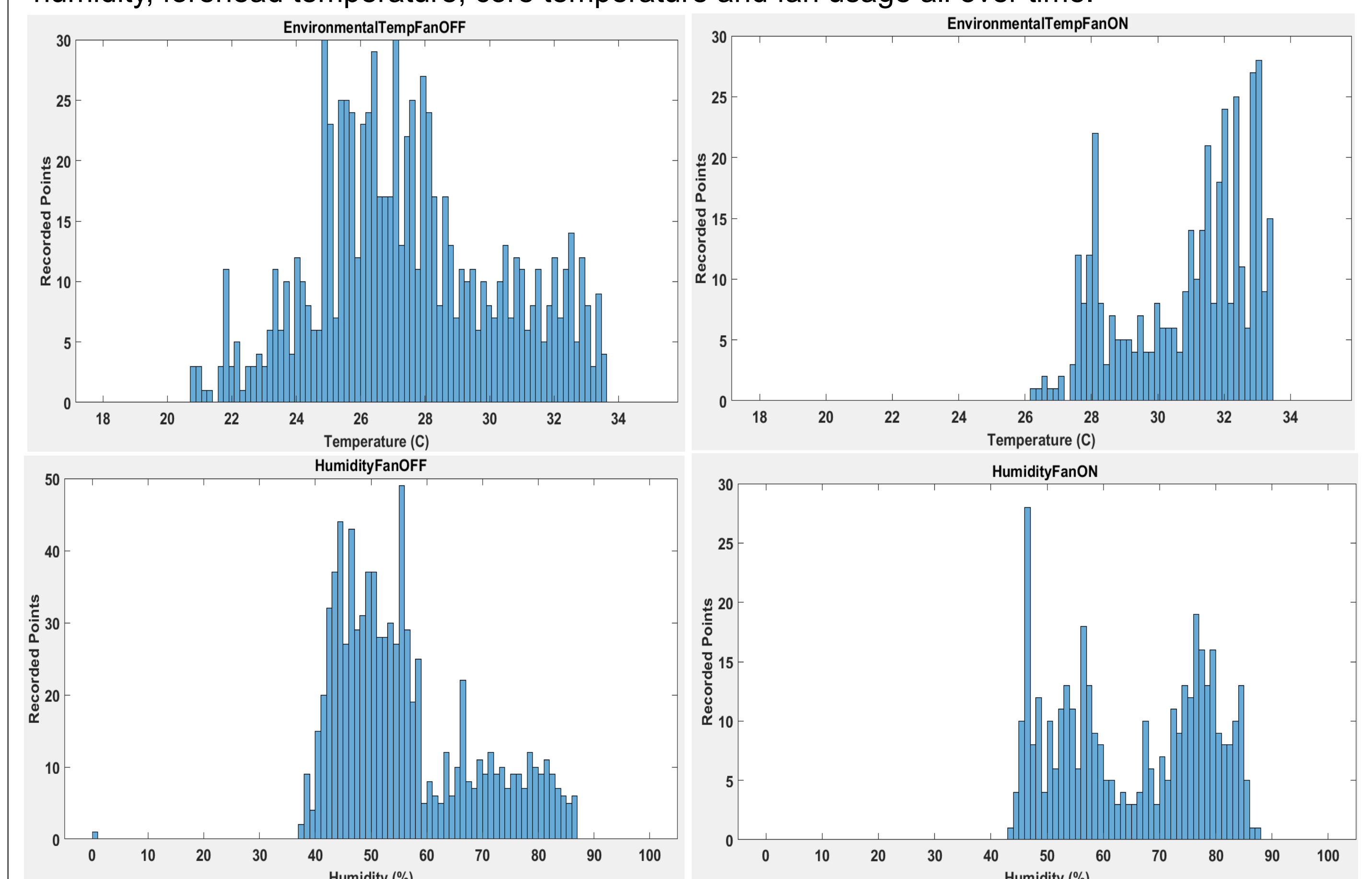


Fig.9 Histograms of Environmental temperature and humidity with fan on or off for all volunteers.

Volunteer	Ambient Temperature when the fan is turned on (C)	Ambient Temperature when the fan is turned off (C)	Ambient Humidity when the fan is turned on(%)	Ambient Humidity when the fan is turned off(%)
A	27.5	33.3	72	62
B	N/A	N/A	N/A	N/A
C	28.8	33.1	69	65
D	N/A	N/A	N/A	N/A
E	26.6	28.2	71	51
F	N/A	N/A	N/A	N/A
G	31.0	31.2	83	50
H	28.5	28.4	78	49
I	32.9	27.8	69	44
J	31.0	26.3	80	47
K	27.2	33.4	79	57

Fig.10 Statistics from the experimentation. When N/A - the fan was not used.

## Conclusion

- This project provides a useful preliminary study for developing an adaptive thermal comfort systems. The adaptive element (the fan) proved to be hugely variable between individuals. The results have suggested that there may however be usable reference points (for an adaptive system) such as the crossover of core temperature and forehead temperature.
- It has been noted from our results a strong tendency for individuals to turn on the fan at delayed points from when the temperature reached a maximum and to avoid incremental fan usage. It is suggested that this 'overcompensating' could well be avoided by an adaptive system.

## Further work

- Relation of skin temperature and use of a fan is yet to be fully understood and modelled. However the results of this project will inform the plan and experiment further in the development of adaptive thermal comfort.
- The environmental profile achieved by the climate chamber was a bit different for every volunteer and malfunction occurred in some instances due to extreme temperature outside of the chamber in July/Aug 2018. Further data collection is needed during more stable and mild weather, e.g during Autumn.