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Differences In Thermal Comfort State Transitional Time Among Comfort Preference Groups

Pimpatsohn Sae-zhang, Matias Quintana and Clayton Miller
School of Design and Environment, National University of Singapore, Singapore

INTRODUCTION

Plenty of thermal comfort research has primarily focused on steady-state conditions, yet the actual thermal environment is naturally transient and dynamic over time. Many researchers have acknowledged transient environments and deviated to anticipate non-uniform human thermal response to better building design (Mihara et al., 2019), however, there is a lack of studies on the transition rate a person takes to arrive at a stable thermal comfort level.

This work aims to quantify ***individual differences and their time taken for the transition*** between comfort and uncomfortable state on occupants during their normal day-to-day activities. We employ ***a micro-EMA field study*** strategy to capture in-situ real-world data in a fully operating building. Then, we classify the subjects into three different groups or clusters, based on the ratio of their preference responses to one's overall votes. The three groups are *Group 1* who prefers a cooler environment, *Group 2* who feels comfortable and prefers no change and *Group 3* who prefers a warmer environment. We found that subjects based on comfort preferences experience a similar transition time behaviour amongst respective groups.

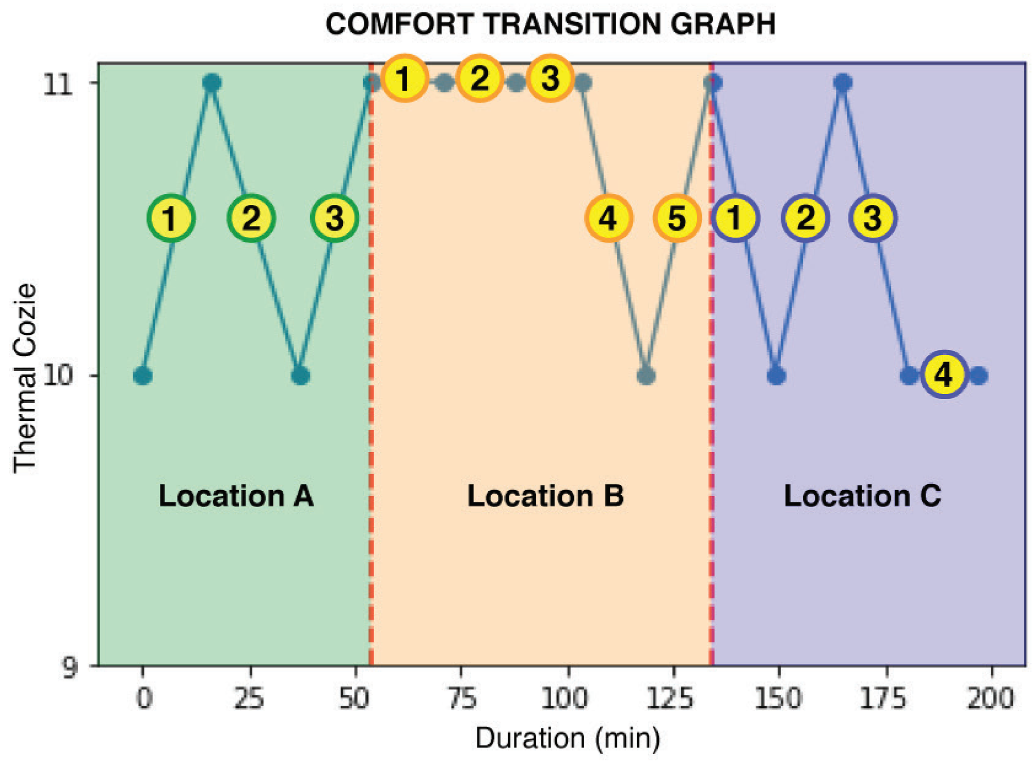


Figure1a Comfort transition graph of one participant at different locations. A total of 8 thermal transitions are shown as increasing or decreasing slopes.

METHODS

The ***thermal comfort feedback*** was collected using a 3-point scale where *'9'* denotes that the subjects prefer the environment ***to be warmer***, *'10'* denotes that the subjects are ***thermally comfortable*** (no change is needed) in such surroundings and *'11'* denotes that the subjects prefer the environment ***to be cooler***. When the feedback is given, occupants' location and timestamp are captured and processed via the subject's smartphone that is paired with the smartwatch and Bluetooth beacons for indoor localisation inside the building. The ***time difference between two data points*** for each subject was calculated if the timestamp of a data point does not exceed 15 minutes with the previous data point and if they were given in the same location. If there is no change in the subjective vote, the time is accumulated until a change occurs. Once there is a change, the accumulated time is recorded for such a transition.

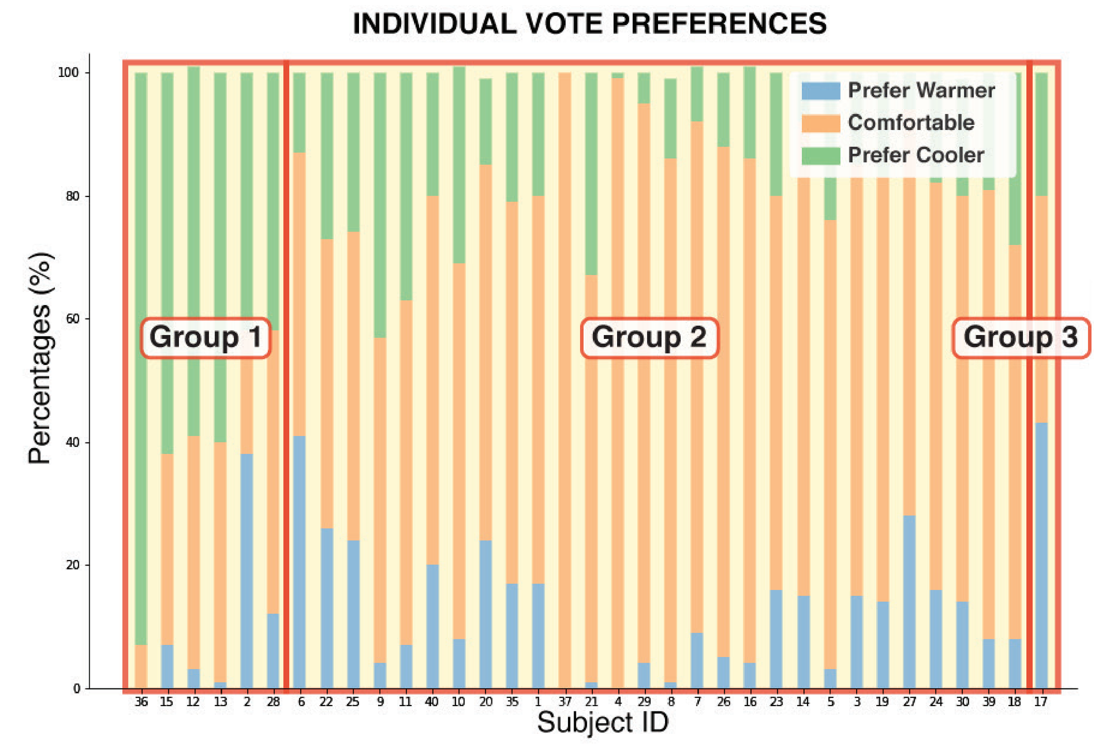
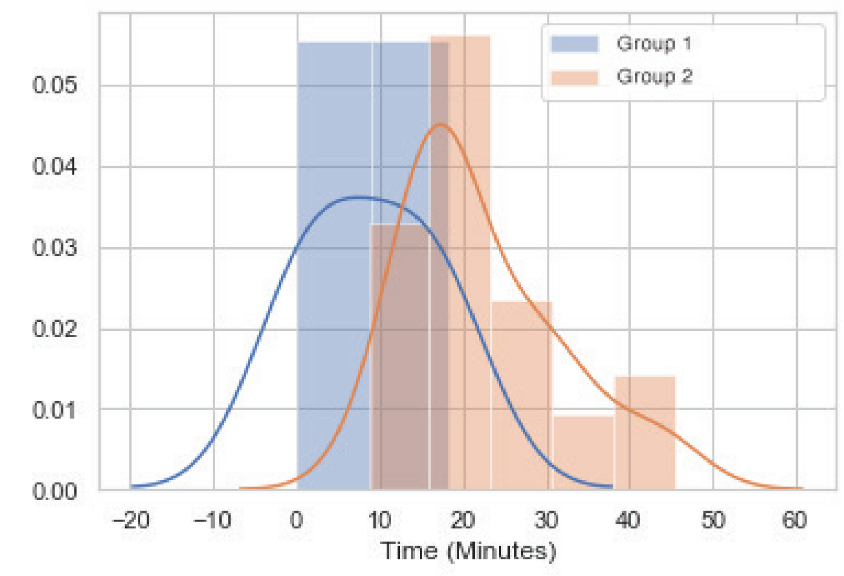
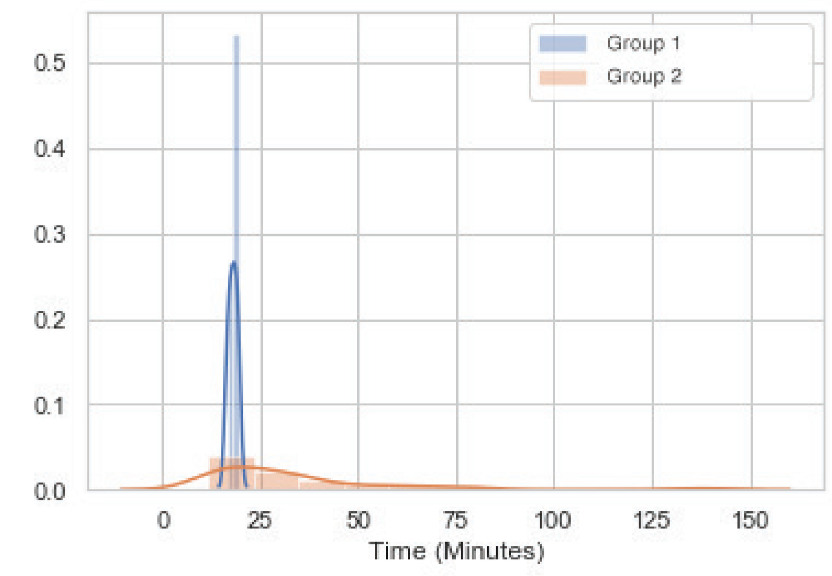


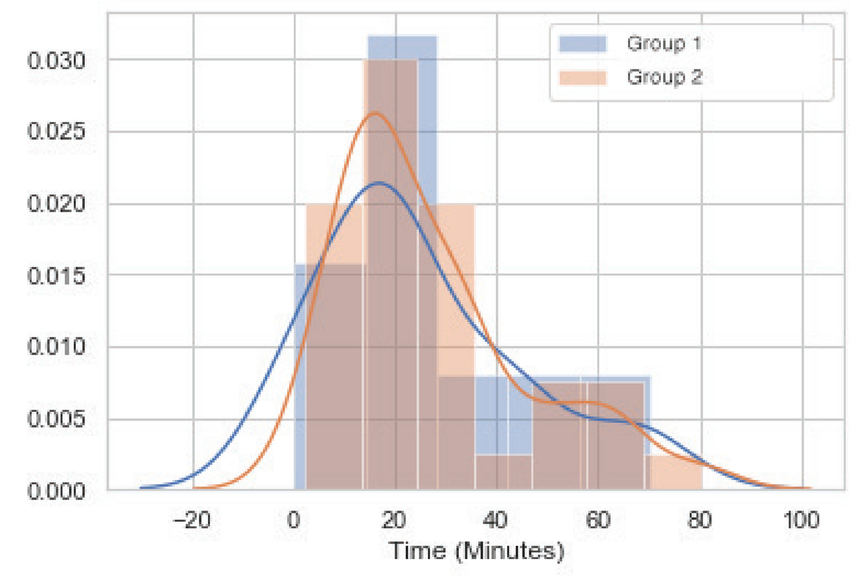
Figure1b Percentage distribution of thermal votes of all 30 subjects (normalized to ratios with respect to each subject's total votes)



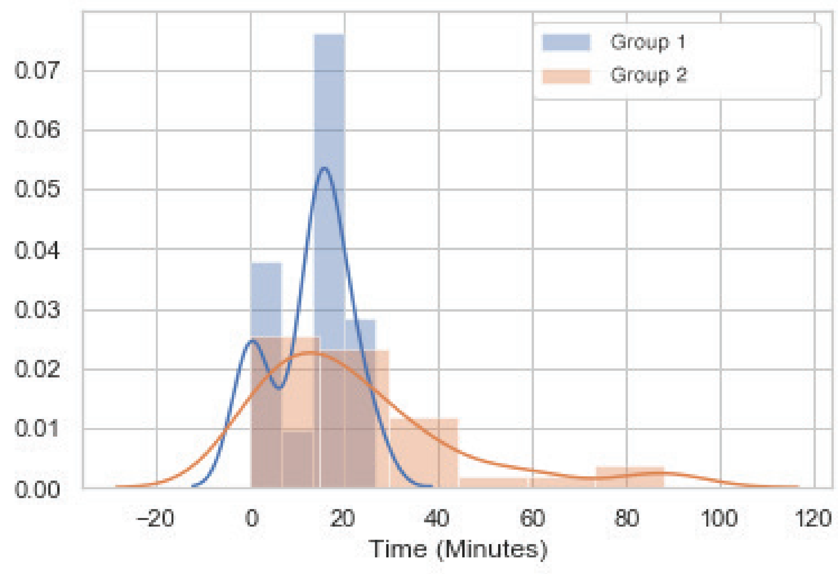
(a) 'Prefer Warmer' to 'Comfortable' (9-10) shows the PC takes a shorter time than the NC.



(b) 'Prefer Cooler' to 'Comfortable' (11-10) shows that both preference groups have similar transition times.



(c) 'Comfortable' to 'Prefer Warmer' (10-9) shows that two drastic adaptability when both groups were thermally comfortable.



(d) 'Comfortable' to 'Prefer Cooler' (10-11) shows a long tail distribution for the NC and bimodal distribution for the PC.

Figure2 Distribution graphs of thermal transition times that each cluster takes for each transition behaviour.

RESULTS & DISCUSSION

This paper focuses on the changes from being thermally uncomfortable to being thermally comfortable and vice versa. There are 2 types of transitions, namely 1) ***Uncomfortable to No Change State*** and 2) ***Comfortable to Uncomfortable State***.

In the transition from uncomfortably cold to comfortable (9-10) state, subjects from *Group 1* took less time on average than *Group 2*, 8.9 minutes and 22.4 minutes respectively: ***Subjects who preferred to stay in a cooler environment were able to reach their comfortable state faster***. The absence of *Group 3* could imply that the air supplied was not cool enough to be thermally comfortable for this group. The participant in this group might either genuinely be in a constant state of uncomfortably cold or possibly take a long time to reach their comfortable state. Contradicting the 'prefer warmer' to 'comfortable' (9-10) transition where *Group 1* was found to change faster than *Group 2*, *Group 1* group ***took lesser time for changing from comfortable to uncomfortably hot*** (10-9), 18 minutes and 33.5 minutes respectively. Both *Group 1 and 2* do not have members that have experienced going from uncomfortably hot to comfortable (11-10) state, but shared similar average transition time, 25 minutes and 27.1 minutes respectively, shown in *Figure 2(b)*. These results can be understood as the effectiveness of the existing cooling systems in the buildings; regardless of the predominant preference in *Group 1 and 2*, subjects in both groups adapt and reach a comfortable state in roughly the same time on average.

This may imply that, even if *Group 1* is formed by users who voted 'prefer cooler' the most, subjects in this group do not really rather a cooler environment but are just ***more sensitive to colder environments***. Contrastly, *Group 2* has a much wider range in transition times as high as 100 minutes to feel uncomfortable, highlighting the characteristics of the group as they ***stayed in their comfort for a much longer time***.

CONCLUSION

The results suggest that thermal ***transient behaviours are much more dynamic*** and significantly ***influenced by its immediate ambient context*** but at the same time, ***the trend of subjective responses is reflected in the transition time***. Overall, Group 1, with the average of 8.9, 18 and 25 minutes, took shorter durations than Group 2 which experienced a change at 22.4, 33.5 and 27.1 minutes, upon reaching and leaving their comfortable states.

ACKNOWLEDGEMENT & REFERENCES

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Mihara, K., Sekhar, C., Tham, K. W., Takemasa, Y., & Lasternas, B. (2019). Effects of temperature, air movement and initial metabolic rate on thermal sensation during transient state in the tropics. Building and Environment, 155, 70-82. doi:10.1016/j.buildenv.2019.03.030