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Desktop polling station for real-time building occupant feedback

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Abstract

There is a growing interest in investigating how thermal comfort models perform in practice. Studies have indicated that occupant expectations to the indoor climate may affect their notion of thermal comfort. However, it is a challenge to collect the data needed for investigating this further. This paper reports on the first experiences with a Desktop Polling Station (DPS) developed for fast collection of vast amounts of subjective and objective data in real building environments. The experience from a pilot study indicated that the DPS in fact is able to collect vast amount of data over a short time period. This data may give new insights to how occupants deal with their notion of thermal comfort in offices, e.g. through expectation.

Keywords – Thermal indoor climate, human factors, real-time feedback, post occupancy evaluation

1. Introduction

The concept of a Predicted Mean Vote (PMV) as a design criterion for thermal comfort [1] was developed under controlled conditions in laboratories. These criteria are widely accepted and used for design goals in building design projects. However, a number of experiments [2-4] demonstrated that there seems to be a deviation between the “theoretical” PMV-based thermal comfort and the “actual” thermal comfort in real buildings. Reasons for this deviation may be ascribed to be the occupant *expectations* to the indoor climate and the possibilities of occupants to adapt themselves or their environment to maintain thermal comfort. The so-called adaptive comfort models [2,5] rely on the recognition of these behavioural and psychological factors. Even the heat balance-based PMV has been suggested to be expanded with an *expectation factor* so the index becomes PMV_e [6].

The prevailing adaptive models and the PMV_e model result in different temperature ranges of thermal comfort. This is because the data for the models are obtained in different climates. This could be because *expectations* to the indoor climate can be different in different climates and cultures. More studies are needed to understand the expectation factor in relation to thermal comfort in real buildings. One challenge of research in this area is the scale and frequency of the data needed. Typically web-based indoor environment surveys only sample each participant once [7]. This can be problematic because the indoor environment is not homogeneous but dynamic: the indoor conditions change throughout the day. Furthermore, the participants are likely to forget to answer the survey due to their work tasks [7]. Therefore new efficient methods to collect vast amounts subjective and objective data simultaneously in a fast and reliable manner are desired. This paper describes such a method and the first experiences using it.

2. Method

A desktop polling station (DPS) for fast and reliable collection of vast amounts of data has been developed. The DPS can be seen in Fig. 1. The DPS is a small box with an interface where building occupants can be asked for their subjective assessment of the indoor climate while sensors continuously are logging objective air temperature, relative humidity, CO_2 concentration, and illuminance level on an internal memory card.

The subjective assessment is based on a questionnaire containing questions about clothing level, thermal sensation, thermal preference, air quality, air velocity and lighting level. The questionnaire uses the 7-point ASHRAE-scale [8] to assess the subjective thermal sensation. The questions regarding air quality, air velocity and lighting level were also adopted into this form but only with a 5-point scale to shorten the survey time. Table 1 displays all questions and their subjective voting scale. The whole questionnaire takes 1-2 minutes to answer.

Fig.1. The Desktop Polling Station.

Table 1. Questionnaire implemented in the desktop polling station.

What is your clothing level right now?*						
T-shirt, shorts (socks, shoes, underpants)	T-shirt, trousers (socks, shoes, underpants)	Shirt, trousers (socks, shoes, underpants/shirt)	Thick shirt, trousers (socks, shoes, underpants/shirt)			
How do you experience the temperature right now?						
Very cold	Cold	Slightly cold	Comfortable	Slightly warm	Warm	Very warm
Would you like the temperature to be						
Warmer	No change	Colder				
How do you experience the air quality right now?						
Very good	Good	Acceptable	Bad	Very bad		
How do you experience the air velocity right now?						
Standing still	Low	Not low/not high	High	Very high		
How do you experience the lighting level right now?						
Very bright	Bright	Comfortable	Dark	Very dark		

*clothing in brackets assumed for all occupants.

The desktop polling station was designed and built to be located at each participant's workstation making the interaction easier. This allows the occupants to participate in studies without them having to change location, time schedule or environment. Interactions with the DPS are encouraged trough prompts for regular subjective feedback by blinking diodes in the buttons. The conceptual design of how the DPS collects fast data can be seen in the Fig. 2.

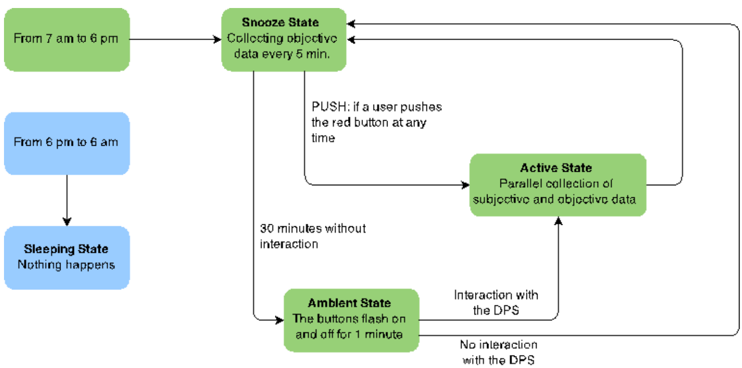

Fig. 2. Flow diagram of the user interactions

2.1 Current limitations

The measurement of relative air velocity, mean radiant temperature (MRT), and activity level is missing if the subjective votes are to be compared with the PMV-index. Measuring relative air velocity with a unit like the DPS is currently not solved. However, Table 1 contains a subjective question about air velocity to a least get a notion of the magnitude of this parameter. Measurement of MRT could be conducted be constructing a low-cost globe thermometer e.g. as suggested by Konis [7] from which the MRT can be derived. Measuring activity level of the occupant (i.e. metabolic rate) is also not solved. Since both relative air velocity and activity level are based on assumptions, it is suggested to make a sensitivity analysis of these parameters to identify the uncertainty related to these estimations.

Another limitation is that the DPS user can only vote using the discrete category steps of the 7-point ASHRAE-scale. Future developments could be to apply a more continuous scale like the visual analogue scale.

2.2 Pilot field study

A pilot field study was conducted on the lower floor (2nd) of a 5-story open plan air-conditioned office in Aarhus, Denmark. The purpose was 1) to test the robustness of the DPS for data collection, 2) testing the rate of user interaction and experience, and 3) to gather data for the development of a conceptual analysis method to identify the expectation factor based on DPS data. Data was collected at the workspaces of ten participants with a distribution of gender at 40% female and 60% male. All participants had similar work task that involved computer work for the majority of their work hours. The participants were prompted for a subjective assessment every half hour. They were allowed to adapt their clothing level during the day if they wanted (first question every half hour is on current clothing level, see Table 1). To increase the probability for votes under steady state conditions, all participants were instructed only to interact with the DPS if they had been at their desk for at least half an hour. Otherwise they should ignore the prompt from the DPS.

3. Results

The following section presents 1) the potential for data collection using this DPS, and 2) an analysis of the actual thermal sensation vote and the corresponding PMV. The participants expressed that the air quality was either acceptable or good and there was no significant correlation between these votes and any of the objective data.

3.1 The potential for data collection

Despite of some minor technical issues, a total of 371 subjective assessments of the indoor environment were collected from ten participants on the course of ten workdays. This is a relatively vast amount of assessments within the few days considering that 4655 observations were collected in a time period of three years in the research project SCATs [5] which is the basis for the adaptive comfort criteria in the European standard EN 15251. In average each DPS collected 4.7 participant responses per day but the most active participants had 8-12 assessments per day. The DPS technology therefore has a high potential for gathering large amounts of subjective votes and objective data.

3.2 Thermal sensation – the expectation factor

Assuming that the activity level was constantly 1.2 Met and the relative air velocity was 0.1 m/s, a difference between the actual Thermal Sensation Vote (TSV) and the corresponding calculated PMV was observed. A theory is that difference between TSV and PMV is due to an expectation factor since no other adaptive behavior was observed in the pilot field study case. The preliminary findings showed a tendency for a relationship between the derived expectation factor and air indoor temperature (Fig. 3) and a relatively weaker relation between the expectation factor and running mean outdoor temperature (Fig. 4). Uncertainty due to assumption and measurement error is not added.

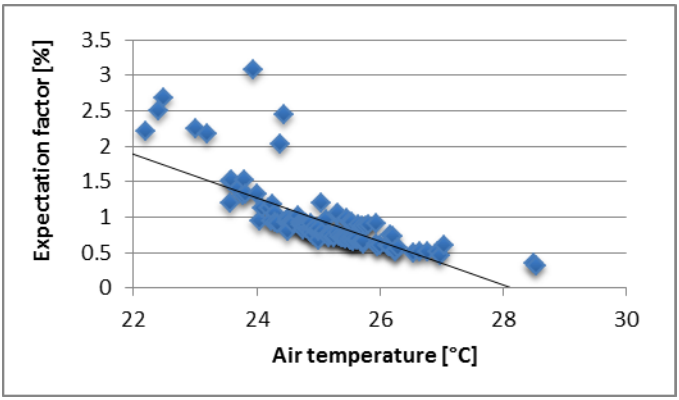

Fig. 3. The expectation factor in relation to the air temperature.

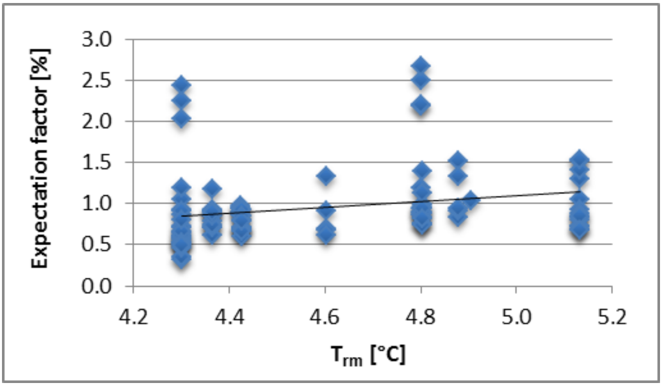

Fig. 3. The expectation factor in relation to the the running mean outdoor temperature.

It is important to note that the pilot study was very small in number of participants and limited to a very short period to make any sound conclusions for development of indoor climate models.

4. Conclusion

The first experience with the offline DPS was that the technology is rather stable in terms of gathering data. Short informal interviews with the participants of the pilot study that a survey period ten days where the DPS pushed for assessments every half hour is close to the limit of survey fatigue for the majority of the participants (for some it was already too much). However, a total of 371 votes within ten days demonstrated that the DPS technology has the potential to collect vast amount of data in a short period of time – data which is valuable for various purposes in indoor climate research and for development of more user-driven control of indoor climate systems.

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