Building and Environment 116 (2017) 17–29

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

# Short- and long-term acclimatization in outdoor spaces: Exposure time, seasonal and heatwave adaptation effects

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ARTICLE INFO

*Article history:*
Received 1 December 2016
Received in revised form
2 February 2017
Accepted 3 February 2017
Available online 8 February 2017

*Keywords:*
Thermal sensation
Transitional spaces
Outdoor thermal comfort

ABSTRACT

We investigate acclimatization effects on outdoor thermal perception. Steady-state conditions were ensured by a prolonged stay of participants (N = 16) in a test chamber prior to the subjects' exposure to outdoors, i.e. after five consecutive hours under thermal comfort conditions indoors. After that, subjects walked in a controlled pace around the external precincts of the facility and were asked to vote on their thermal sensation and preference according to a standard questionnaire: a) immediately, b) 15 min and c) 30 min after they left the controlled indoor environment. Altogether 36 sessions were performed with varying outdoor conditions over winter, spring, and summer 2015. We evaluate acclimatization effects on the subjects' thermal perception against predictions of the outdoor thermal conditions in terms of UTCI (Universal Thermal Climate Index) and the derived DTS (Dynamic Thermal Sensation). ANOVA results showed that UTCI conditions remained unchanged throughout the 30-min exposure time outdoors, but differed between seasons, whereas the subjects' thermal perception votes differed both between seasons and the times of votes. Reduced thermal sensitivity was noticed in winter and spring at the first vote, resulting in greater prediction bias (underestimation), which was attenuated at higher temperatures and during longer exposure times. An initial overshooting at the first vote towards cool response occurred at moderate temperatures in summer, increasing bias (overestimation), which was also attenuated with increasing temperature and time of exposure. Acclimatization to a heatwave in summer lead to enhanced heat tolerance just after it, with acclimatization loss in the subsequent session.



## 1. Introduction

The paper is concerned with the time of residency factor when conducting outdoor comfort studies. Short-term acclimatization in terms of space residency plays an important role on the perceived thermal sensation, with a longer exposure of a person to the thermal environment leading to more accurate perceptions of it. Analogously, long-term acclimatization as influenced by seasonal aspects can affect thermal expectancy factors as regards outdoor spaces. Somewhere in between lies the time frame around sudden changes in atmospheric conditions, as in the case of heatwaves, which is also investigated in this paper.

Skin temperature strongly affects how one perceives the thermal environment. Höppe [1] shows through computer modelling of the skin temperature that in the cold at least 3 h would be needed for steady state to occur in the heat exchange between skin and air temperature; in warm conditions, steady state is reached more quickly but nevertheless only after approximately half an hour.

According to the physiological concept of Alliesthesia [2] "a given stimulus will arouse either pleasure or displeasure according to the internal state of the stimulated subject", thus stepping from thermal homogeneity to transient outdoor conditions should create immediate responses that would then diminish with time of exposure. When a subject experiences a thermally static environment for longer periods, "with no opportunity for the body to interpret the 'usefulness' of a stimulus for thermoregulation", there

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http://dx.doi.org/10.1016/j.buildenv.2017.02.001
0360-1323/

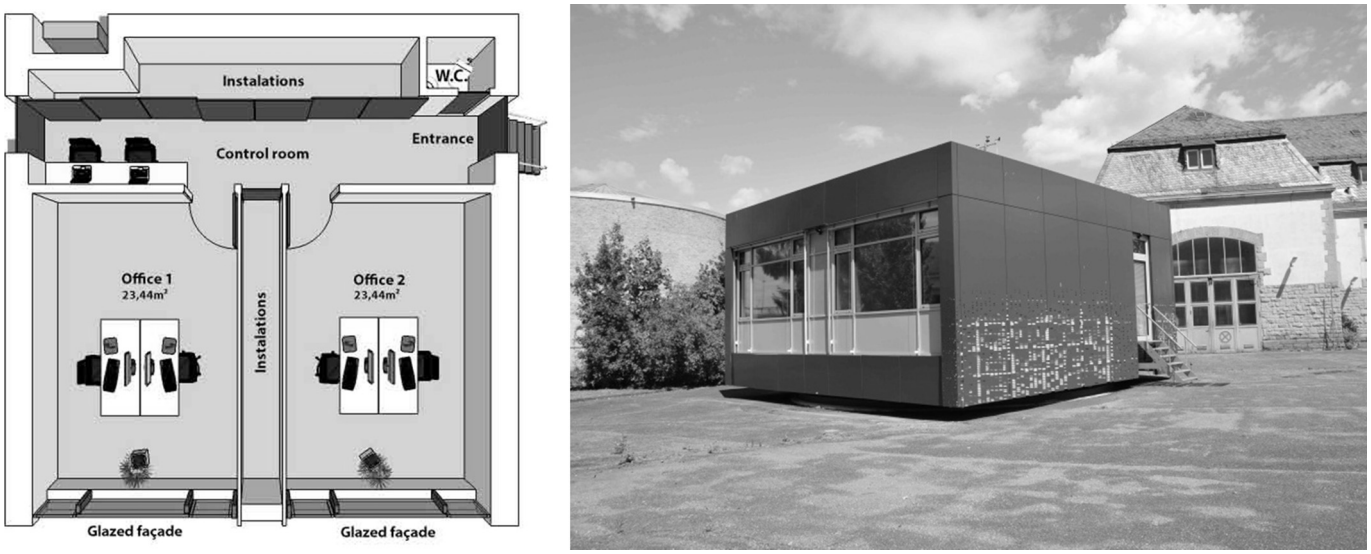


**Fig. 1.** Floor plan and the LOBSTER test facility in summer (July 2015).

**Table 1**
Equipment characteristics.

| Specification | Variables measured | Length of measurement | Measurement interval | Accuracy |
|---|---|---|---|---|
| Comfortmeters ALMEMO 2690 | air temperature (Ta), globe temperature (Tg), relative humidity (RH), air speed (v) | During 5-h session | 1/10 s | Ta and Tg: ±0.05 °C RH: ±0,5% v: ± 0.1 m/s |
| Handmade weather station, adapted on a tripod with two HOBO U12-011 dataloggers; one placed insided a plastic globe painted of grey (Ø 10 cm), and other inside a 50 cm long PVC tube for providing shade while allowing natural ventilation to the logger. Spot measurements with anemometer (Testo 416 Mini-Vane anemometer), attached to tripod | air temperature (Ta), globe temperature (Tg), relative humidity (RH), wind speed (v) | 1 h and a half (1 h prior to the surveys to "acclimatize equipment") | 1/min (except wind speed; spot measurement at the moment of the questionnaire filling) | Ta and Tg: ± 0.35 °C RH: ±2.5% v: ±0.2 m/s |

is a greater chance that he will more effectively experience thermal pleasure or displeasure under sudden transient conditions. De Dear [3] pointed to the relevance of the alliesthesia concept to the planning of transitional spaces and tested this hypothesis in a climate-chamber study with participants exposed to step-up and step-down temperature [4]. Results described the more immediate effect in step-up than in step-down changes on reported thermal sensation; the authors suggested the accuracy in thermally perceiving a given thermal environment to be closely related to cutaneous thermoreceptors.

In this context, the residency time question or the time needed for short-term acclimatization gains in importance because interviewing people with a short residency time can create bias in interpreting the survey results. As pointed out by Wu and Mahdavi [5] "A disregard of thermal evaluation processes pertaining to transitional states may result in inappropriate temperature settings, inefficient thermal controls, and poor thermal comfort conditions". Similarly, if the thermal processes involved in transitioning from indoors to the outdoor environment area are not accounted for, it might result in an inadequate interpretation of the thermal perception reported by pedestrians. This will put an unnecessary burden on urban planners to seek for more intricate solutions from climate-responsive urban design.

As for seasonal, long-term acclimatization, the adaptive comfort concept [6] is based on changes in thermal preference over different seasons, with increased tolerance towards heat in summer and towards cold in winter. In a field study in Israel, Pearlmutter et al. [7] observed how expectations to seasonal changes in weather conditions affect the seasonal acclimatization factor.

There will be a great need for Europeans to adapt to heatwave conditions, which will likely increase in frequency due to global climate change. As pointed out by Koppe et al. [8], effective interventions, measures and policies to protect the health of vulnerable Europeans will thus need to be developed and evaluated. However, studies of human acclimatization effects to heatwaves are still sparse. Lam et al. [9] comment that most of such studies use modelling approaches and report on how Australians reacted in terms of thermal perception comfort during a heatwave and after it. Results showed that park visitors felt significantly hotter and wore less clothing for the same ranges of the Universal Thermal Climate Index (UTCI) during heatwave than under non-heatwave conditions.

In this paper we explore short- and long-term acclimatization effects from subjective responses to outdoor conditions of participants who took part of a controlled field experiment over three seasons in a temperate climate (Karlsruhe, Germany). As in the