THERMAL COMFORT WHEN BOARDING TRAINS – PRELIMINARY DATA

Lisa Kelly, Simon Hodder, Ken Parsons
Environmental Ergonomics Research Centre, Loughborough University, Loughborough, Leics, LE11 3TU
Contact person: L.Kelly@lboro.ac.uk

INTRODUCTION

Subjective information about thermal comfort, in steady-state conditions, on trains has been studied (Stennings 2007, Underwood and Parsons 2005) but little is known about comfort immediately after boarding a train. Two studies were conducted examining thermal sensation following a change of environment:

1. A laboratory experiment designed to simulate the transition between two thermal environments
2. A field experiment to collect data whilst boarding trains

METHODS – EXPERIMENT 1

A repeated measures design was employed using 6 females, mean age 23.3 years (SD=2.6), the experiment was conducted from January to February 2009. Participants were asked to attend the Environmental Ergonomics laboratory at the same time of day on three separate occasions, each time presented with a different thermal condition. The order of conditions was determined by 2, 3x3 latin squares. Experimental conditions were set which gave predicted mean votes (PMV) of +2 warm, 0 neutral and -2 cool (ISO 7730). Participants' wore a standardised clothing ensemble for the experiment (jeans 100% cotton, t-shirt 100% cotton, jumper 70% cotton 30% polyester) and wore their own trainers and socks. Environmental parameters were logged using an Eltek/Grant squirrel data logger at 10 second intervals. Skin temperature was measured at one second intervals using the Ramanathan 4 point method. Participants' were then weighed nude then clothed prior to entering the chamber. Subjective ratings of sensation, preference, pleasantness, comfort, stickiness and draught were reported before, immediately after and every 5 minutes after entering the chamber until 30 minutes had passed. Participants were weighed pre and post exposure, for five minutes at the end of the experiment and nude once more.

RESULTS

Table 1 shows the mean (and standard deviation) environmental conditions inside the chamber for each of the test sessions. The table shows little variance in environment for each of the three test conditions.

Table 1 Mean environmental conditions –thermal chamber

	Neutral	Warm	Cool
ta	24.72 (0.49)	30.95 (0.19)	18.13 (0.46)
tr	24.75 (0.72)	30.77 (0.36)	18.30 (0.46)
Air velocity	0.19 (0.04)	0.19 (0.04)	0.21 (0.04)
RH	49.26 (1.44)	31.32 (5.71)	68.7 (5.17)
PMV	0.1	1.8	-1.7

Table 2 shows the mean conditions outside the chamber overall, and per condition, and indicates that the environment outside the chamber was relatively stable overall.

Table 2 Mean environmental conditions – outside chamber

	Neutral	Warm	Cool

ta	17.61 (1.01)	17.88 (1.06)	16.94 (1.56)
tr	17.65 (0.96)	17.93 (1.07)	16.98 (1.43)
Air velocity	0.02 (0.15)	0.02 (0.01)	0.02 (0.02)
RH	37.63 (5.75)	38.17 (2.51)	44.40 (4.34)
PMV	-1.7	-1.6	-1.8

Sensation: Sensation scores at 30 minutes and on exiting were analysed using a Friedman's ANOVA which determined a significant difference in sensation (p=0.001). A post-hoc Wilcoxon Signed Ranks test established that this occurred in the Neutral and Warm conditions (p=0.027 and p=0.028 respectively).

Mean skin temperature and sensation: Figure 1 compares mean skin temperature and sensation at 30 minutes and immediately after exiting. The coloured lines indicate the condition which preceded the exit. It can be seen that although mean skin temperature during the warm exposure (AMV=1.9) was higher (1˚C) than that in the neutral condition (AMV=0.8), the sensations reported when exiting the chamber were the same (AMV=-1.3) is higher following the warm condition, the same sensation as the neutral condition is experienced. The cool condition shows no real change in sensation as well as a higher sensation score on exiting than the other two conditions.

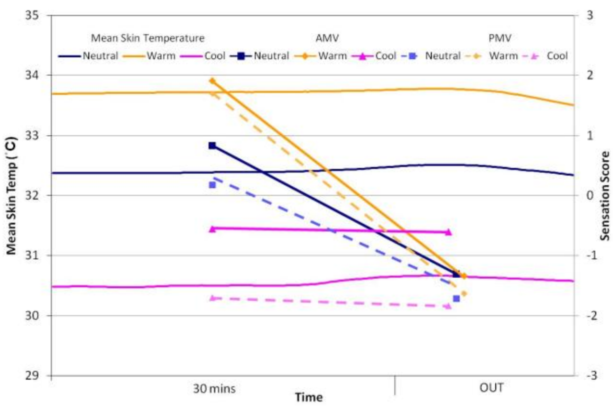

Figure 1 Mean skin temperature, Actual Mean Vote and Predicted Mean Vote

Sensation and Predicted Mean Vote: Results show that PMV model inaccurately predicted sensation in the cool condition both inside and outside the chamber (see Figure 1). Results for the warm and neutral conditions corresponded to PMV values both inside and outside the chamber.

Mass: In all conditions participant's mass increased after entering the chamber and decreased during the experiment. During the five minutes of weighing at the end of the experiment, mass fluctuated in all three conditions. The cold condition has the greatest mass loss and the greatest amount of sweat trapped in clothing (see Table 3) and the neutral condition has the greatest amount of sweat evaporated.

Table 3 Mass

	Mass Loss (nude)	Dry weight of clothing	Wet weight of clothing					Sweat trapped	Sweat evaporated
			1	2	3	4	5		
N	0.042 (0.015)	1.860 (0.221)	1.870 (0.225)	1.870 (0.224)	1.870 (0.227)	1.867 (0.224)	1.870 (0.223)	0.010 (0.013)	0.032 (0.013)
W	0.045	1.843	1.867	1.864	1.861	1.864	1.863	0.024	0.021

	(0.028)	(0.197)	(0.218)	(0.217)	(0.218)	(0.216)	(0.215)	(0.027)	(0.009)
C	0.058	1.857	1.896	1.900	1.899	1.898	1.895	0.039	0.019
	(0.074)	(0.220)	(0.228)	(0.223)	(0.222)	(0.224)	(0.226)	(0.084)	(0.015)

CONCLUSIONS

It can be seen from Table 2 that although outside conditions were similar, sensation scores following the cool condition were noticeably different (although not significant). This, therefore, indicates that people moving into an environment that is similar to the one they have previously inhabited, may find it more thermally acceptable than PMV would predict. PMV did predict the gradient of sensation change for all three conditions and more accurately predicted sensation in the neutral and warm conditions (both inside and outside the chamber). So, when people move to an environment where conditions differ from the previous one, PMV may be able to predict sensation immediately after entering.

Results indicate that although there is no change in skin temperature, for both the warm and neutral conditions, there is a sharp decrease in sensation on exiting the chamber. Interestingly, the final sensations for the warm and neutral conditions were almost exactly the same even though skin temperatures and previous sensation scores were different.

METHODS – EXPERIMENT 2

The field experiment consisted of two train journeys involving experimenters and two participants travelling on a train, participants recorded their thermal comfort on the platform, when boarding and when alighting the train. Experimenter 1 boarded the train at the previous station to measure the environment on the train; the other recorded the conditions on the platform. The equipment used to measure the environment was the same as used in Experiment 1 with the logging interval set to 1 second. Experimenter 1 completed a return journey from Loughborough to Leicester, Experimenter 2 and the two participants completed a return journey from Sileby to Syston(see Figure 2 for train line diagram).

An independent measures design was employed on mornings during March 2009 with four females (mean age 23.65, SD=1.88) who had already completed the laboratory experiment. The methodology employed was similar to Experiment 1; participants attended the Environmental Ergonomics laboratory and the five thermistors were attached to the skin and the same clothing ensemble was used. These were attached to an Eltek/Grant data logger logging at 1 second intervals. Participants were required to record their thermal comfort with an abbreviated selection of the scales used in Experiment 1 (using only sensation, preference and stickiness). Due to the nature of the experiment, it was necessary to extend the sensation scales to +5 and -5 to accurately record sensation in outside environments. An Olympus WS-110 voice recorder was used to verbally record thermal comfort information; and enable any changes in sensation to be rapidly recorded.

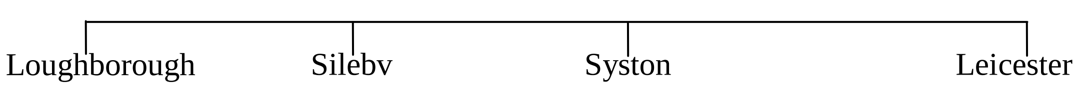

Figure 2 Train line diagram

After participants were prepared with the equipment, all members travelled to Loughborough station where Experimenter 1 was left to board the train. Experimenter 2 and the two participants then travelled to Sileby station. On arriving at the station, subjective thermal comfort information was recorded at 5 minute intervals for approximately 25 minutes until the train was in sight. Once the train could be seen, participants continually recorded information as the train pulled into the platform, whilst boarding and as the train pulled away from the platform. Participants then recorded information as they alighted the train at the next station; this procedure was repeated for the return journey.

RESULTS

Two experiments were conducted on two separate days; the environmental conditions on the train are shown in Table 4. The table shows that environmental conditions on the train were almost exactly the same.

Table 4 Mean environmental conditions – on the train

	Journey 1	Journey 2
ta	19.42 (0.30)	19.42 (0.30)
tr	18.84 (0.37)	18.83 (0.38)
Air velocity	0.05 (0.08)	0.05 (0.07)
RH	45.10 (0.91)	45.12 (0.90)
PMV	-1.2	-1.2

The environmental conditions on the platforms are shown in Table 5, for each experiment there are two sets of conditions for the two stations. The table shows that each day was cold, damp and had a low mean radiant temperature.

Table 5 Mean environmental conditions – on the platform

	Journey 1 Sileby	Journey 1 Syston	Journey 2 Sileby	Journey 2 Syston
ta	8.77 (0.23)	10.43 (0.04)	8.32 (0.11)	9.30 (0.19)
tr	12.10 (0.59)	12.04 (0.47)	8.68 (0.20)	9.91 (0.26)
Air velocity	0.28 (0.13)	0.26 (0.16)	0.58 (0.57)	0.66 (0.36)
RH	79.87 (0.37)	78.05 (0.13)	75.72 (1.65)	66.21 (0.64)
PMV	N/A	N/A	N/A	N/A

Sensation: The sensation scores for participants are shown in Figure 3, with the changes over the course of the experiment illustrating a sensation 'profile' for each participant. The two peaks on the graph indicate sensation when boarding and sitting on the train. The graph shows that all participants have an increase in sensation upon boarding the train which then decreases after they have been sitting in the carriage for a few minutes.

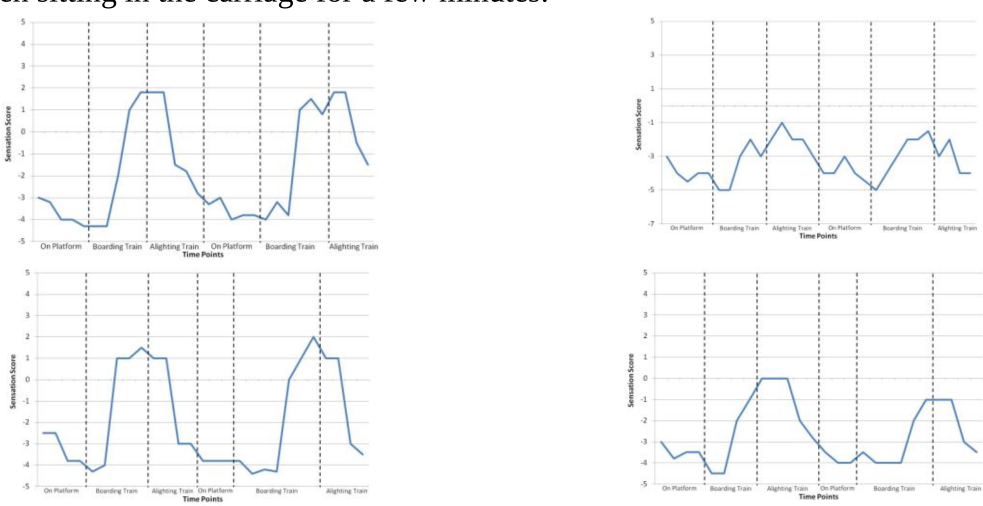

Figure 3 Sensation scores during field experiment

Mean skin temperature: Participants' mean skin temperature for both experiments is shown in Figure 4. Once on the platform, there is a gradual cooling of the skin until boarding the train where there is a sudden peak which continues until the participants' alight at the next station.

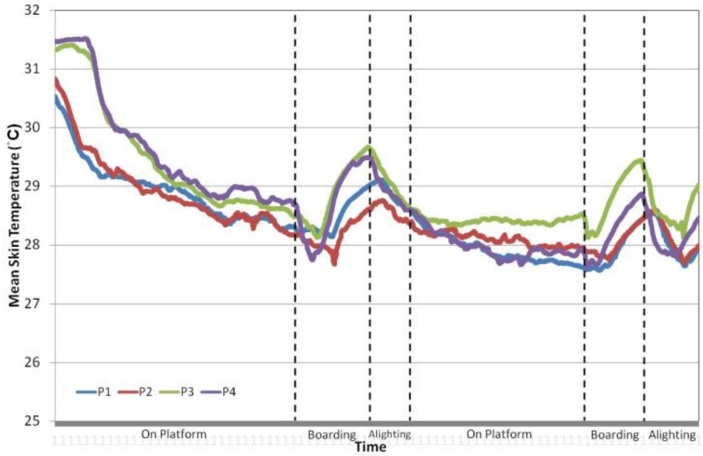

Figure 4 Mean skin temperature during field experiment

CONCLUSIONS

The data obtained regarding the environmental conditions on the train suggest that, on an overcast day, the environment is relatively constant. Outside conditions for the second experiment were slightly cooler that the first, however, subjective scoring did not reflect this.

After boarding the train, subjective scoring showed a peak in sensation which then decreases (also termed an 'over-shoot' in sensation). This effect has not been previously seen in field studies because the sampling rate has not been at a high frequency. This effect has been noticed in laboratory studies; further data collection will determine whether this occurs under all environmental conditions.

Mean skin temperature gradually decreases whilst participants were standing on the platform and reaches an approximate minimum of 28°C. On boarding the train, skin temperature rapidly increases until the participant alights again where there is a rapid decrease in temperature, coinciding with a decrease in thermal sensation.

ACKNOWLEDGEMENTS

This research is funded by the EPSRC and Rail Research UK.

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