A COMPARISON OF DATA COLLECTION METHODS FOR MEASURING THERMAL COMFORT ON TRAIN JOURNEYS

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INTRODUCTION

Traditionally measurement of subjective thermal comfort has been carried out using paper-based questionnaires (Underwood and Parsons 2005). For this reason, preliminary trials were conducted on trains with paper questionnaires recording subjective thermal comfort. The trials revealed that this method may not be suitable under certain journey conditions (e.g. inclement weather, when standing on a platform or getting on and off the train). For this reason, other methods of data collection were examined.

Personal Digital Assistants (PDAs) have been increasingly used in research when obtaining subjective information (Bernhardt et al. 2007, Dale and LeFlore 2007, Jamison et al. 2001, Raymond and Ross 2000, Trapl et al. 2005) as they can significantly reduce transcription time. In addition, missing data can be eliminated and entries can be time and date stamped enabling detection of entries completed retrospectively. Verbal reports have also been used in research (Ericsson and Simon 1980, Ryan and Haslegrave 2007) as they can provide a rich data source as well as extending the potential experimental population to those with reduced reading and writing skills. Verbal reports are also a way of capturing subjective responses when paper-based or PDA systems are impractical to use.

The experiment aimed to determine whether PDAs and verbal reports are suitable for collecting thermal comfort information on train journeys. The experiment was also designed to establish which method would be most preferred by participants' for use on train journeys.

METHODS

A repeated measures design was employed using 9 males and 9 females. Mean age of the total group of participants was 26.67 years (± 8.6) (male mean = 30.88 years ± 10.7; female mean = 22.46 years ± 1.66). The experiment was conducted during February and March 2008. Participants were asked to attend the laboratory at the same time of day on three separate occasions, using a different data collection method each time. The order of presentation of the methods was determined by 6, 3x3 latin squares. Participants wore their own clothes which were the same for each test session and were seated throughout their time in the chamber. Participants were exposed to the same environment on each test session and the conditions inside the chamber were varied in an attempt to replicate the changing environment on a train. See Figure 1 for chamber set-up.

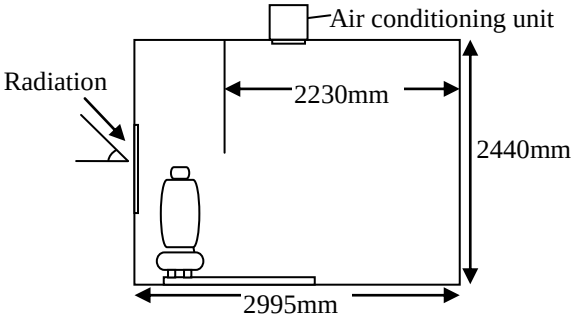

Figure 1 Chamber set-up

On entering the chamber, the participant completed the first part of the questionnaire immediately. Subsequent sections were completed every 15 minutes after this without prompting. Participants were provided with a clock to enable them to complete the next section when required. Following completion of the hour in the chamber, each participant completed a questionnaire rating the method used, on a number of different scales.

Physical parameters were logged using an Eltek/Grant squirrel data logger at 1 minute intervals. Air temperature was measured using shielded thermistors at 3 points beside the participant. A HUMICAP (by Vaisala) 180 meter measured relative humidity. Air velocity was measured using a Biral hot wire anemometer. Radiant temperature was measured using a black globe thermometer.

Three methods of data collection were compared during the experiment: Paper, PDA and Voice recorder. The paper questionnaire consisted of an A5 booklet, split into sections, containing questions concerning subjective assessment of thermal comfort. Each section was placed on a separate page to aid completion. Participants were required to select their answer either from pre-coded options or write their response in the relevant area. Subjective scores were recorded in a table provided in each section using scales supplied on the front page of the booklet. Scores for overall sensation and any particular areas of discomfort could be written in the table rows.

An HP iPAQ 114 Classic Handheld PDA was used. The questionnaire was located in a Microsoft Excel workbook and was identical to the paper-based questionnaire. Separate sections were located in different worksheets and labelled accordingly. Participants were required to input answers in the relevant sections using the stylus and on-screen keyboard. The PDA also had an associated prompt sheet showing the thermal scales.

The Philips Voice Tracer 7655 was used during the experiment. An associated prompt sheet reminded participants of information to provide (e.g. time, date) as well as the thermal scales. Participants either stated the value (e.g. a rating of '2.5') or the associated label (e.g. 'Warm to Hot') for each scale.

The six subjective scales used to assess subjective thermal comfort were: sensation, preference, pleasantness, comfort, stickiness and draught (ISO 10551 2001). Participants' were required to assess how they felt using the scales and provide an appropriate corresponding score.

Performance criteria for the data collection methods were set prior to the experiment: (1) Preference – assessed using questionnaires; (2) Reliability – errors in data recording e.g. missing data; (3) Time – the final time taken for each participant to complete the method.

RESULTS

The environmental conditions in the chamber throughout each experiment were consistent (see Figure 2) it can, therefore, be concluded that any differences in subjective scoring should be due to method alone.

Figure 2 Air temperature per condition

Thermal sensation: Participants' gave thermal sensation scores according to a 7-point bi-polar scale (-3 = cold, 0 = neutral, +3 = hot) (ISO 10551 2001). Figure 3 shows the average thermal sensation scores according to method. The graph shows that when scoring on the PDA, people tended to choose higher values than when using the other two methods.

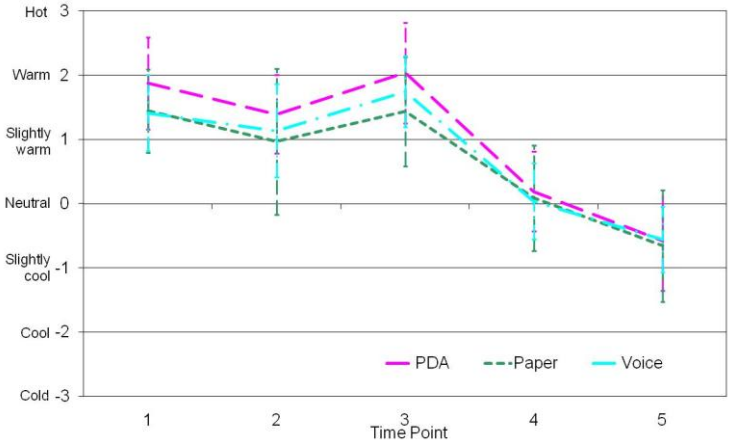

Figure 3 Mean thermal sensation scores by method

A Friedman's ANOVA determined no significant difference in scores at time points 2, 4 and 5. However, statistics indicated there were significant differences at time points 1 and 3 ($p=0.032$ and $p=0.038$ respectively). The post hoc Wilcoxon Signed Ranks test determined a significant difference in scores at time point 1 between the paper method and the PDA ($p=0.033$) and the voice method and the PDA ($p=0.018$). At time point 3 there is a significant difference in scores between the paper method and the PDA ($p=0.006$). Results indicated that people score higher when using the PDA at time points 1 and 3.

Performance criteria: Results for the performance criteria are shown in Table 1. For the preference scores, a low number indicates the participants' rated this method positively.

Table 1 Performance criteria results

		PDA	Paper	Voice
Preference	- Easy to use	3	2	1
	- Easy to incorporate into journey	1	2	3
	- Comfortable using it on a train	1	2	3
	- Need practise	3	1	2
	- Awkward to use	3	1	3
	- Negative impact on journey	1	2	3
Reliability – missing or ambiguous data		4	0	14
Time taken – final completion time (secs)		140.9 (SD=59.6)	70.4 (SD=32.9)	74.4 (SD=20.7)

CONCLUSIONS

Subjective scoring: As the paper method has been previously tested it was considered to be the 'gold standard' against which the other two methods should be assessed. The results have shown that, at certain points, there are significant differences in subjective scoring, when using different methods. However, in practical terms, the differences are relatively small and may not be practically significant. It is reasonable to conclude, therefore, that all three methods are valid in measuring subjective thermal comfort.

Preference and Usability: Participants rated the voice recorder as the easiest method to use; however, there was a lack of confidence using it and it was noted that it would be the most difficult to incorporate into a journey. It was also rated as the method they would feel most uncomfortable using on a train due to the embarrassment of talking in public. This result may have been affected by the nature of the information discussed, rather than participants' being uncomfortable talking in public (as many people are happy to talk openly via mobile phones). It was also noted that other passengers may find the talking an irritation. It is therefore important to consider the context of the environment and the nature of information being communicated when considering employing this method. It was felt the voice recorder would have the most negative impact on a train journey which, again, could be due to embarrassment rather than the method itself.

Participants felt confident using the paper method; however, many noted that its ease of use was affected by the need to have a hard surface to write on. Interestingly though, it was rated as the least awkward method to complete. The paper questionnaire was rated as the method requiring the least amount of practise; which may be due to participants' familiarity with completing paper-based questionnaires. When considering the journey, paper was rated as the least suitable method at most journey stages (e.g. when standing on the platform). These results reinforce information determined during preliminary work. Overall participants rated the paper method quickest to complete which corresponds with the actual completion times obtained.

The PDA was rated as the easiest method for incorporation into a train journey, in addition to it being the method participants felt most comfortable using on a train. It affords participants a greater level of privacy and is inconspicuous among other rail users, who may also be using similar technologies. As a result, it was also rated the method having the least negative impact

on the journey as a whole. Conversely, it was rated as the method least easy to use and highlighted as requiring the most practise for effective use. This aspect must be considered should the method be employed in future.

These results indicate that participant's method preference can be determined by more complex factors than usability alone. Aspects, such as the ability to blend-in and situations that may cause embarrassment were key drivers in participant's decisions of preference. It is the experimenter's role to limit negative aspects and promote the positive attributes of a particular method, in order to elicit accurate responses from participants' ensuring results are not confounded by other factors.

Objective measurements: From a total of 1788 data points from the subjective scales 4 data errors occurred on the PDA and 14 when using the voice recorder. The PDA errors generally consisted of data entry problems which could be mitigated with software preventing invalid data being entered. Missing data was the main source of error on the voice recorder, with participants omitting to report a score. Ambiguous answers were also an issue when transcribing the data. A more thorough training procedure and stressing the importance of accurate responses could lessen these errors.

The time of completion for each method determined the paper questionnaire was quickest, followed by the voice recorder. The PDA took the longest, however, participants noted that this could be a positive feature as it provides an activity, on what could otherwise be, a monotonous train journey.

The results of the experiment have shown the PDA to be the method most preferred by participants. They noted how they would be able to blend-in and integrate the PDA with their train journeys. There are however negative aspects of this method as it may be difficult to complete at certain points of the journey. Further field work is required to determine whether this method (or a combination of methods) is suitable for a real-world rail journey.

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