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The integration of three field survey datasets in Athens, Greece: transformation of five-point to seven-point thermal sensation scale

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Abstract
The integration of the datasets from three different field surveys on thermal sensation conducted at eight different sites of the area of Athens, Greece was examined. All three surveys were carried out with similar methodologies so data integration can be considered meaningful. The surveys included micrometeorological measurements and questionnaire-based interviews during different seasons focusing on human thermal sensation. The participants self-reported their thermal sensation classified in predetermined classes, i.e. very cold, cold, cool, neither cool nor warm, warm, hot, very hot. However, despite the similarities, one of the surveys used a five-point (±2, ±1, 0) thermal sensation scale whereas the other two a seven-point (±3, ±2, ±1, 0) scale. The present study focused on the transformation of the five-point to a seven-point thermal sensation scale. The middle and extreme classes of both scales were considered to coincide, so the rescaling method involved fitting a common sigmoid curve in all three datasets and reassigning points ±1 of the five-point scale to ±1 and ±2 of the seven-point one. For this purpose, air temperature, grey-globe temperature and Physiological Equivalent Temperature were used as possible independent variables.
Keywords: field surveys; thermal sensation; data integration; PET

1. Introduction

Rating scales are commonly used to measure a qualitative attribute. A fully labeled 7-point scale is suggested to provide the greatest benefits to respondents and researchers alike (Eutsler and Lang 2015). Thermal sensation has been evaluated using various scales, while several rescaling methods have also been examined (Nikolopoulou et al. 2018). The 7-point (±3, ±2, ±1, 0) scale is the most widely used (ISO 10551, 2001). The RUROS (2004) project however, targeting outdoor spaces in the urban context across Europe adopted a 5-point scale (±2, ±1, 0) for participants to self-evaluate their thermal sensation. The National Kapodistrian of Athens (NKUA) (Pantavou et al. 2013) and the Agricultural University of Athens (AUA) (Tseliou et al. 2016) projects following similar protocols with RUROS, adopted 7-point scales. All three projects were carried out in Athens, Greece, covering eight different urban sites in six different municipalities. The aim of the present study is to transform the 5-point thermal sensation scale of RUROS project to a 7-point scale in order to be integrated with the databases of NKUA and AUA. The integration of the three datasets could be used for a spatial assessment of thermal conditions.

2. Methods

The RUROS project involves data of about 9,268 participants from seven different European cities including Athens, Greece (n=1,503). The NKUA (n=1,706) and AUA (n=2,286) projects were also conducted in Athens, following similar methodologies. All three field surveys focused on thermal sensation, employed questionnaire-based interviews and mobile weather stations monitored outdoor air temperature (T_{air}), relative humidity (RH), wind speed (WS) and grey globe temperature (T_{gl}). The participants self-reported their thermal sensation in predetermined classes of a scale, namely actual thermal sensation (ATS). The rescaling method involved the identification of a function, adequately describing the relationship ATS=f(X) for all projects, where X, an appropriate physical parameter or index related to thermal sensation. Apart from T_{air} and T_{gl}, Physiological Equivalent Temperature (PET) was also selected as an independent variable (X). PET was estimated using RayMan software. The form of the relationship ATS=f(X) suggested a sigmoid function. The initial attempts when the actual means of the independent variables per ATS classes were considered, lead to wide dispersion of the curves representing the various projects, even at a seasonal level. To remedy that we calculated the difference between the mean for each specific ATS class and the seasonal mean of each of the independent variables: $\Delta X = X_i - X$, where X is T_{air}, T_{gl} or PET seasonal mean value for i=±3, ±2, ±1, 0 (the ATS class).

The sigmoid function was fitted twice on the RUROS dataset; first, considering the 5-point scale to ensure that the function fits the data and then, assuming that the middle (0) and extreme classes (±2) of the 5-point scale coincide with the middle (0) and extreme classes (±3) of the 7-point scale respectively, the points ±1 of the 5-point scale would have to be reassigned into ±1 and ±2 of the 7-point one. This could be done by fitting a new sigmoid curve to the three known points of the 7-point scale (-3, 0, +3).

Table 1. Cut-off points of mean grey globe temperature (T_{gl}, °C) and physiological equivalent temperature (PET, °C) between actual thermal sensation (ATS) classes -1 and -2, and +1 and +2 for rescaling the 5-point scale of RUROS project to a 7-point scale.

	Summer		Winter		Transitional	
ATS	**T_{gl}**	**PET**	**T_{gl}**	**PET**	**T_{gl}**	**PET**
-1 to -2	30.2	30.3	20.0	19.6	24.1	24.1
1 to 2	31.2	31.5	21.6	21.3	26.9	27.6

3. Results

Pearson correlation showed that ATS was better correlated with T_{gl} than T_{air} or PET for NKUA (r^2=0.809, p<0.01) and AUA projects (r^2=0.453, p<0.01), while ATS was better correlated with PET for RUROS (r^2=0.319, p<0.01) project. Thus, T_{air} was excluded from further analysis. The sigmoid functions fitted to the three datasets ($0.68 \leq R^2 \leq 0.99$) showed a closer match between the RUROS and the NKUA and AUA datasets, especially in summer and the transitional season, for both T_{gl} and PET. After reassigning the 5-point extreme classes (±2) of RUROS to the 7-point extreme ATS classes (±3) the sigmoid function was fitted again at the three points of ATS (0, ±3). The threshold between the classes -1 and -2, and between +1 and +2, was the average of the respective seasonal cut-off points of mean T_{gl} and PET (Table 1). The distribution of the rescaled ATS compared to those reported is presented in Figure 1.

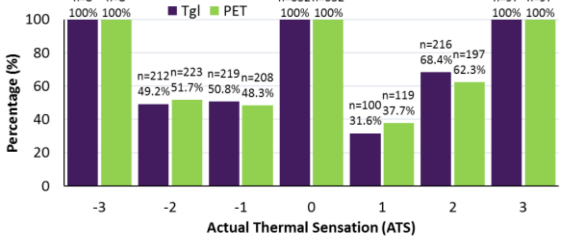

Figure 1. Distribution of actual thermal sensation (ATS) of 7-point scale compared to the 5-point of RUROS project. Classes 0 and ±3 of the 7-point scale are identical to those of the 5-point scale (0 and ±2 respectively). Classes ±1 of the 5-point scale are reassigned into classes ±1 and ±2 of the 7-point one.

4. Conclusions

The present work addressed the transformation of thermal comfort scales. The thermal sensation scale used in RUROS project prevented the integration of datasets with two additional projects conducted in Athens. The integration of RUROS, NKUA and AUA datasets comprise a database of 5,495 participants which could be used for a spatial assessment of thermal conditions.

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References

Eutsler J., and Lang B. (2015), Rating Scales in Accounting Research: The Impact of Scale Points and Labels, Behavioral, *Research in Accounting*, **27**, no. 2: 35–51.

ISO 10551 (2001), Ergonomics of the Thermal Environment-Assessment of the Influence of the Thermal Environment Using Subjective Judgement Scales, International Organization for Standardization, Geneva.

Nikolopoulou M., Kotopouleas A., and Lykoudis S. (2018) From indoors to outdoors and in-transition; thermal comfort across different operation contexts, 10th Windsor Conference: Rethinking Comfort, NCEUB, Windsor, UK.

Pantavou K., Theoharatos G., Santamouris M., and Asimakopoulos D. (2013) Outdoor Thermal Sensation of Pedestrians in a Mediterranean Climate and a Comparison with UTCI, *Building and Environment*, **66**: 82–95.

RUROS (2004) Rediscovering the Urban Realm and Open Spaces, *http://alpha.cres.gr/ruros/*.

Tseliou A., Tsiros I.X., Nikolopoulou M., and Papadopoulos G. (2016), Outdoor Thermal Sensation in a Mediterranean Climate (Athens): The Effect of Selected Microclimatic Parameters, *Architectural Science Review*, **59**, 190-202.