

CAN BRAIN ACTIVITY BE USED AS AN OBJECTIVE MEASURE OF THERMAL PERCEPTION?

Sarah L. Davey¹, Geoff Holman², Michael J. Tipton¹.

1. Dept. of Sports & Exercise Science, University of Portsmouth, Portsmouth, UK.

2. Dept Electroencephalography, St Mary's Hospital, Portsmouth

Contact person: sarah.davey@port.ac.uk

INTRODUCTION

Subjective measurements of thermal comfort (TC) and temperature sensation (TS) are used to assess thermal environments, but tend to have large inter-individual variability, making them unsuitable for group descriptions of subjective feelings. As a consequence a more objective measure of thermal perception would be useful.

Associations between electroencephalographic (EEG) activity and thermophysiological measures have been well documented during rest (Dubois *et al*, 1980; Youngstedt *et al*, 1993). In addition, Nielsen *et al* (2001), found a strong relationship between oesophageal temperature (T_{oes}) and the α/β index of electroencephalographic (EEG) activity during cycling in the heat. When a similar protocol was followed, a relationship between the subjective measurement of rating of perceived exertion (RPE) and T_{oes} was established (Nybo & Nielsen, 2001). As TC and TS are correlated with both T_{oes} and RPE (via body temperature), the possibility exists that α/β index reflects TC and TS rather than T_{oes} .

The aim of this study was to determine if a relationship exists between α/β index, body temperature, TC, TS and RPE during exercise in the heat. It was hypothesised that changes in brain activity would be associated with TC and TS, rather than body temperature and/or RPE.

METHODS

Main Experimental design

Following ethical approval and informed consent, the EEG activity of fifteen cortical regions were recorded (Trackit T24, Lifelines, UK) in five physically active males (age 23(1.3) yrs, mass 76.33(11.7) kg, height 178.1(9.5) cm, BMI 24.0(1.9) kg/m²) during three, 20 min periods of cycling at work intensities that elicited 50, 75, and 85% of maximum heart rate, followed by 40 mins of rest. Each trial was conducted in 35°C air, 50% RH. Each participant wore a short sleeved cotton t-shirt and Lycra cycling shorts.

EEG Application & Recordings.

Fifteen Ag/AgCl disk electrodes (Nihon Kohden NE-134A) were affixed to the scalp at sites (Frontal: F₄, F₃, F₇, F₈, Cerebral: C₄, C₃, C_z, Parietal: P₄, P₃ Occipital: O₂, O₁, Temporal: T₄, T₃) according to the international 10-20 classification system (Jasper, 1958). The electrodes were secured onto the scalp by adhesive glue (SLE Collodion adhesive, UK) that was quickly dried by a battery powered air dryer that blew cool air to avoid sweating. Each electrode was filled with electrolyte conducting gel (Ten20 conductive paste A0009) by a large syringe and impedance was kept below 8 kOhms. Impedance was monitored by the digitally displayed ambulatory

recording system prior to the start of the experiment, once the subject entered the chamber and during the experimental trial. Each monopolar recording was referenced to Cz.

Resting EEG was recorded for 2 mins (1 min with eyes open, 1 min with eyes closed) just prior to the onset of exercise. During the exercise periods, EEG recordings were evaluated for 30 s in the last minute of each exercise period. Thirty second EEG recordings were also taken during 2 min rest periods between each exercise period. During the 40 min post exercise period (recovery/cooling period), 30 s EEG recording were taken at 4.5, 9.5, 19.5, 29.5 and 39.5 mins. For each recording the participants were instructed to close their eyes and remain in a stable upright position in both the resting and cycling periods.

Fast Fourier transformation was used to obtain power spectrum areas in α (8-13 Hz) and β (13-30 Hz) frequencies (Nihon Kohden Technology, Japan). Percentage change of α and α/β activity from rest were used as indicators of arousal level (Nielsen *et al*, 2001)

Measurements

Measurements of TC, TS, RPE (See figure 1), HR, and rectal temperature (T_{re}) were taken coinciding with the EEG recordings.

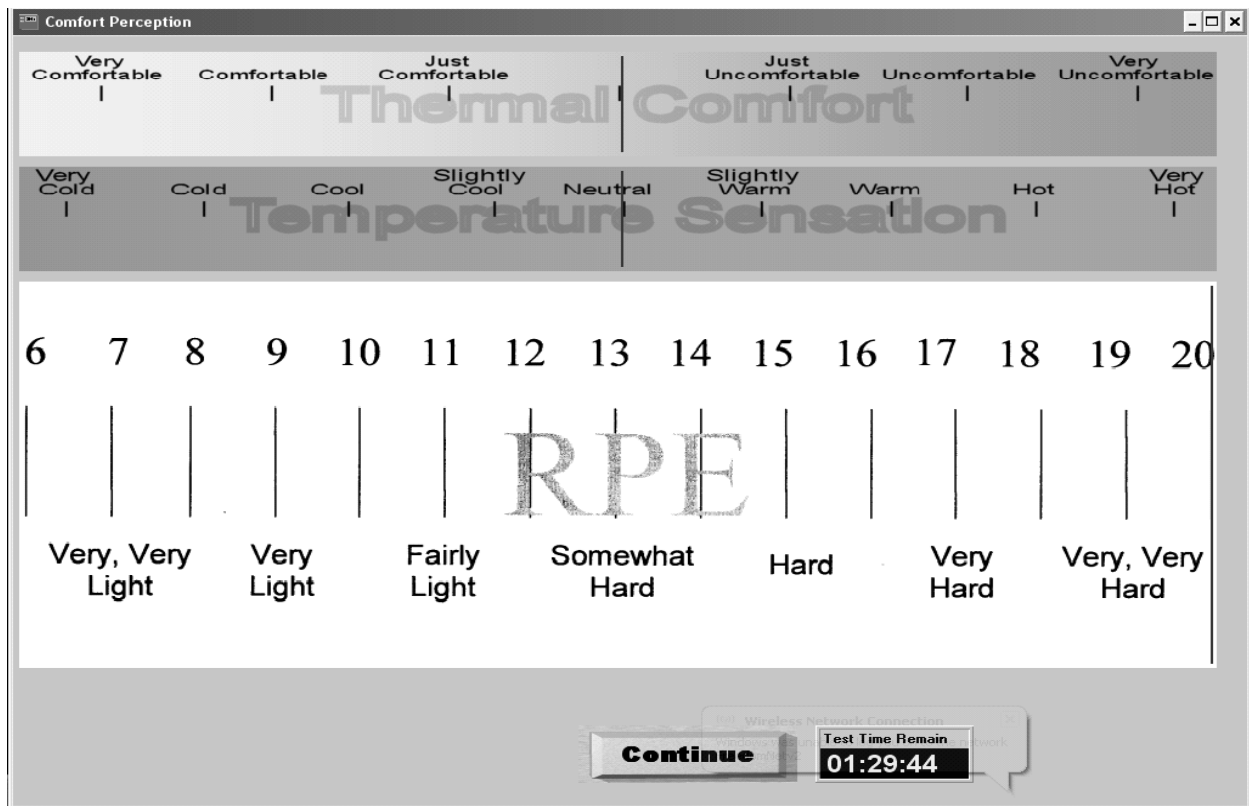


Figure 1. Digitalised Display of Thermal Perceptual Continuous Visual Analogue Scale (Davey *et al*, 2007) and RPE Likert Scale (Borg, 1982)

Statistical Analyses

One-Way ANOVA with repeated measures and paired sample T-tests were performed to evaluate differences within trials. After a significant F test, pairwise differences were identified using a Bonferroni post hoc procedure. Spearman's Rho correlation coefficient was used to examine relationships between variables. Significance was accepted at $P < 0.05$ level. All data were analysed using SPSS version 14.0 and are reported as mean \pm SD.

RESULTS

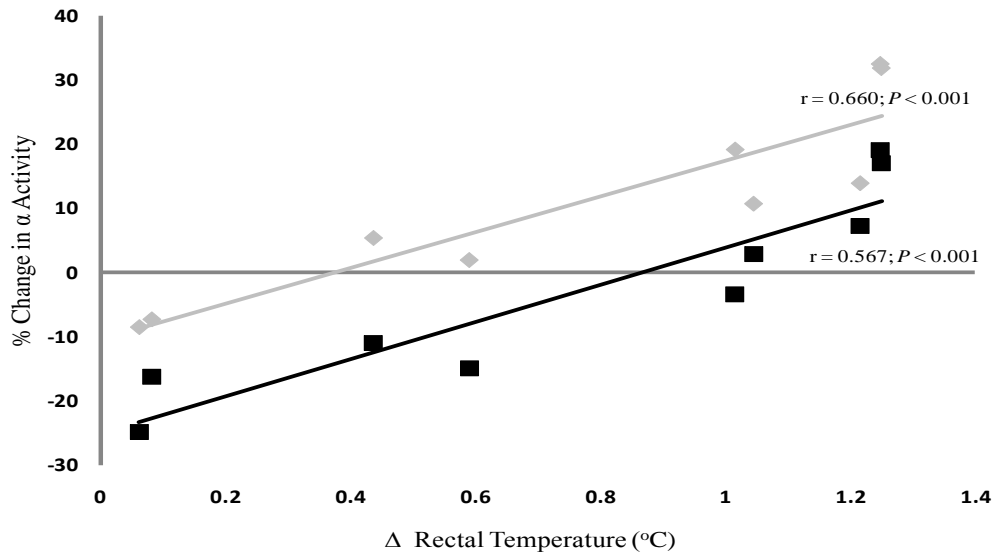


Figure 2. Relationship between F₇ and F₃ % change in α activity and delta rectal temperature during both exercise and recovery period. \blacklozenge = F₇ and \blacksquare = F₃ (n=5).

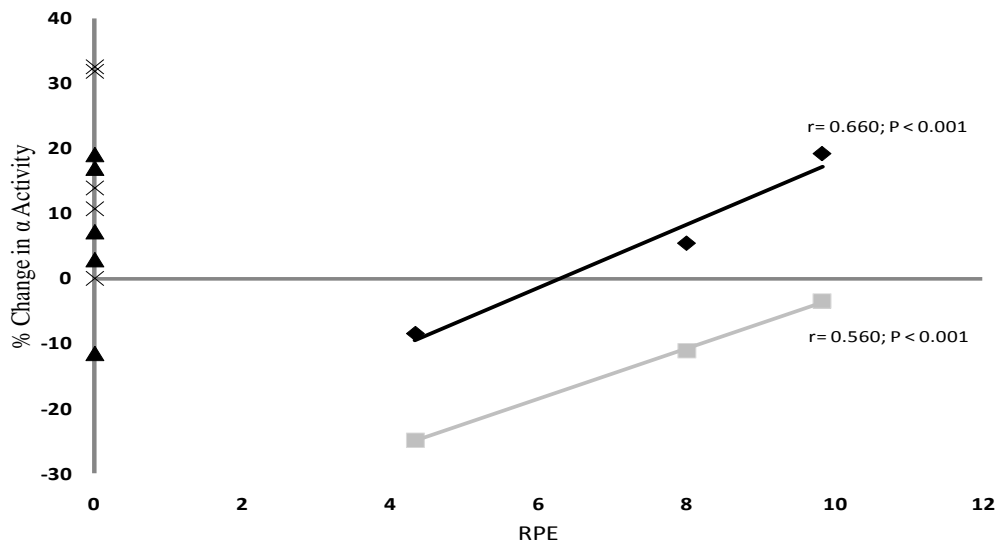


Figure 3. Relationship between F₇ and F₃ % change in α activity and delta RPE during both exercise and recovery period. \blacklozenge = F₇ during exercise, X = F₇ during recovery, \blacksquare = F₃ during exercise, \blacktriangle = F₃ during recovery (n=5).

During exercise T_{re} increased by 1.02 (0.30) $^{\circ}$ C to 38.51 (0.52) $^{\circ}$ C. During the recovery period, T_{re} decreased by -0.34 (0.29) $^{\circ}$ C. Increases in T_{re} were associated with an elevated α activity in the frontal regions F₃ ($r = 0.567$; $P < 0.001$) and F₇ ($r = 0.660$; $P < 0.001$) in both the exercise and recovery period (See Figure 2).

Elevations in % changes of α activity during exercise and RPE were also correlated in the frontal regions of F₃ and F₇ (F₃: $r = 0.560$; $P < 0.05$; F₇: $r = 0.660$; $P < 0.05$). However, this relationship did not exist during the cooling period (See Figure 3). This pattern was also evident in the relationship between RPE and T_{re} ; during exercise a significant association between the two variables was established ($r = 0.856$; $P < 0.001$), but a relationship was not present during the recovery period.

No significant relationships between ΔTC and ΔTS and % changes in α , β , and α/β activity were established. However, significant relationships were evident between ΔTC and ΔT_{re} and RPE during exercise ($r = 0.707$; $P < 0.01$ and $r = 0.856$; $P < 0.01$, respectively).

In order to clarify the relationships between RPE, T_{re} and brain activity, comparisons of % change in α/β activity were undertaken between the exercise and recovery periods when: 1) the participants' T_{re} was at the same temperature 2) the participant's T_{re} differed by +1 $^{\circ}$ C. If RPE was the variable that drives changes in brain activity, it would be expected that a significant difference would occur in both of the aforementioned analyses, as RPE is irrelevant during the recovery period. However, at the same T_{re} , α/β activity was only significantly elevated at the cortical region F₄ (9.00 [22.37] % vs. 33.24 [10.66] %; $P < 0.05$), but a 1 $^{\circ}$ C increase in T_{re} caused an increase ($P < 0.05$) in α/β activity in the frontal regions, F₃, F₄, & F₇ (F₃: 4.31 [32.52] % vs. 58.99 [50.00] %; F₄: 11.50 [12.68] % vs. 48.74 [17.12] %; F₇: -7.59 [10.87] % vs. 55.04 [30.16] %; F₈: 1.78 [17.22] % vs. 45.77 [24.12] %). This result suggests that T_{re} is the main cause for changes in brain activity.

DISCUSSION & CONCLUSIONS

To the authors knowledge this is the first study that has examined the relationships between brain activity and thermal perceptions during exercise in the heat. The results from the investigation suggest that changes in brain activity are not a valid objective measurement of TC and TS. Therefore, the experimental hypothesis is rejected.

In addition, in contrast to previous investigations (Nybo & Nielsen, 2001), during exercise in the heat, brain activity appears to be associated with alterations in T_{re} rather than RPE. A stronger correlation between TC and RPE, than TC and body temperature supports previous evidence that suggests that the subjective measurement of RPE is not just reflective of several physiological processes involved during dynamic activity, but also encompasses other perceptual feelings such as discomfort (Robertson, 1982), including thermal discomfort (Armada-da Silva *et al*, 2004). It also indicates that reducing thermal discomfort should enhance exercise performance.

Finally, the results further support the conclusions that changes in brain activity in response to increasing body and local skin temperatures are localised in the frontal regions of the brain (Craig *et al*, 2000; Nybo & Nielsen, 2001)

REFERENCES

- Armada-da-silva, P., Woods, J., Jones, D. (2004) The effect of passive heating and face cooling on perceived exertion during exercise in the heat. *Eur J Appl Physiol* 91: 656-663.
- Borg, G (1982) Psychological bases of Perceived Exertion. *Med Sci Sports Ex Sci.* 14 (5): 377-38.
- Craig, A., Chen, K., Bandy, D., Reiman, E. (2000) Thermosensory activation of insular cortex. *Nature, neuroscience.* 3 (2): 184-190.
- Davey, S. *et al.* (2007) The reproducibility and validity of visual analogue scales (VAS) that assess thermal perceptions in stable and dynamic, asymmetric environments. *Proceedings of the 12th International Conference of Environmental Ergonomics.* August 19-24, 2007, Piran Slovenia.
- Dubois, M., *et al* (1980) Electroencephalographic changes during whole body hyperthermia in humans. *Electroenceph. Clin. Neurophysiol.* 50: 486-495.
- Jasper, H (1958) The ten twenty electrode system of the international federation. *Electroencephalography and clinical neurophysiology.* 10: 371-375.
- Neilsen, B., Hylig, T., Bidstrup, F., Gozalez-Alonso, J., Chirsoffersen, G. (2001) Brain activity and fatigue during prolonged exercise in the heat. *Eur J Physiol* 442: 41-8.
- Nybo, L. & Nielsen, B. (2001) Perceived exertion is associated with an altered brain activity during exercise with progressive hyperthermia. *J Appl Physiol* 91: 2017-23.
- Robertson, R. (1982) Central signals of perceived exertion during dynamic exercise. *Med Sci Sports Exerc.* 14 (5): 390-396.
- Youndstedt, S, Dishman, K, Cureton, K, and Peacock, L. (1993) Does body temperature mediate anxiolytic effects of acute exercise? *J Appl Physiol* 74:825-831.