Obituary: Professor George Havenith

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Professor George Havenith

Professor George Havenith was an internationally recognised academic in environmental physiology and ergonomics, and a world leader in the fields of integrated human thermoregulation, clothing science, heat-transfer physics and occupational safety.

George began his career with a Master's degree in Mathematical Biology and Human Physiology from the State University of Utrecht in 1983. He subsequently joined the TNO Human Factors Research Institute in the Netherlands as a Research Scientist, where he quickly progressed to lead the thermal physiology group. His work focused on the application of ergonomics and thermal physiology to protective clothing and equipment, particularly for military personnel and first responders.

Although much of this work was highly applied and, by its nature, often confidential, George used this as a foundation from which to develop broader and more generalisable academic research. He had a particular ability to identify principles arising from applied problems that had much wider relevance to the scientific community. This was especially evident in his work on clothing physics, where his early contributions demonstrated that clothing insulation and evaporative resistance should not be regarded as fixed properties, but are substantially influenced by factors including

posture, movement, wind, garment fit and air permeability (Havenith, Heus & Lotens, 1990).

During his time at TNO, George also undertook his PhD, developing ideas that would become central to scientific understanding of individual variation in human responses to heat. His research examined how personal characteristics influence physiological strain during heat exposure, demonstrating that individuals do not respond uniformly to the same environmental conditions and workloads. Alongside environmental and occupational factors, he demonstrated characteristics including aerobic fitness, body mass, body surface-area-to-mass ratio, adiposity and heat acclimation each influence core temperature, sweating and cardiovascular strain.

George subsequently incorporated these individual characteristics into mathematical models of human thermoregulation, highlighting an important limitation of predictions based on an 'average' individual, conditions considered acceptable for the average person would not necessarily provide adequate protection for everyone.

In 1998, George joined Loughborough University as Senior Lecturer in Environmental Physiology and Ergonomics, becoming Professor in 2004. In 2007, he established the Environmental Ergonomics Research Centre, which provided a focus for his expanding programme of research and the development of a growing community of researchers. Throughout his career, George brought together physiology, physics and ergonomics, combining fundamental research with a strong focus on its application to real-world problems.

George made major contributions to understanding the interactions between clothing, the environment and human thermal physiology. His work encompassed protective, occupational, sporting and everyday clothing, demonstrating that while protective garments can reduce exposure to chemical, biological and environmental hazards, they may also impose a substantial physiological burden by restricting evaporative heat loss, increasing metabolic cost, and elevating core temperature and cardiovascular strain. He further showed that measurements of individual fabrics cannot, in isolation, reliably predict the thermal performance of a complete garment (Havenith, 1999; Havenith, den Hartog & Martini, 2011).

A significant part of this work concerned the development and refinement of methods for evaluating clothing using thermal manikins. George helped establish approaches for interpreting these measurements and translating them into an understanding of their physiological consequences for the wearer. Importantly, his work demonstrated that moisture loss from clothing should not automatically be equated with evaporative cooling of the body, strengthening the link between clothing physics and human thermal physiology.

Another major strand of George's research was the development of a body-mapping approach to human thermoregulation. This began with pioneering work measuring regional sweat rates using the Technical Absorbent Method (Smith & Havenith, 2012), providing detailed characterisation of how sweating varies across the surface of the

human body. This approach was subsequently extended to investigate responses in children and older adults. The resulting data and graphical representations of regional sweating patterns informed thermophysiological modelling, the development of segmented thermal manikins, and the design of sportswear and protective clothing.

The body-mapping approach was subsequently extended beyond sweating to examine regional variations in skin temperature, thermal sensitivity and wetness sensation. Collectively, this work provided a more detailed understanding of heat and moisture exchange at the interface between the skin, clothing and environment, and how these local responses contribute to whole-body thermoregulation.

George was also a significant contributor to the development of the Universal Thermal Climate Index (UTCI). The UTCI integrates environmental conditions with sophisticated models of human thermoregulation and clothing, providing a practical framework for assessing thermal stress (Havenith *et al.*, 2012). It has subsequently become widely used in biometeorology, including in assessments of the consequences of climate change for human thermal stress.

In later work through the EU HEAT SHIELD project George investigated the effects of environmental heat on physical work capacity. Working with colleagues, he developed an approach based on maintaining a fixed level of cardiovascular strain, enabling the relationship between environmental heat and reductions in physical work capacity to be quantified. This work contributed to the development of empirical models for predicting losses in work capacity under heat stress, with applications extending to estimates of the economic consequences of occupational heat exposure and increasingly extreme climatic conditions.

George was also closely involved in the development of international standards relating to human thermal environments, serving as a member of ISO TC 159/SC 5/WG 1, Thermal Environments, for more than 35 years. His contributions to standards development were underpinned by collaborative research, helping to translate findings from environmental physiology and ergonomics into approaches that could be applied internationally.

This included work arising from the EU BIOMED project, which contributed to the development of the Predicted Heat Strain approach (ISO 7933), and the COLDSURF project, which contributed to standards addressing temperature limits for cold surfaces (ISO 13732-3). George also contributed to standards concerned with the assessment of heat stress, thermal comfort and cold stress, including those addressing Wet Bulb Globe Temperature, Predicted Mean Vote and Required Clothing Insulation (IREQ). Through this work, he helped bridge the gap between experimental research in human thermoregulation and its application to the protection of people working and living in challenging thermal environments.

George's ability to bridge fundamental and applied research underpinned extensive collaborations with industry and with academic colleagues internationally. His expertise in environmental and thermal physiology was also called upon in expert

witness work for coroners' courts, where he applied his scientific knowledge to understanding the role of environmental exposure in cases of serious harm and death.

George also made a substantial contribution to the wider scientific community, serving in editorial roles for the *European Journal of Applied Physiology* and the *Journal of Applied Physiology*, as well as being a prolific reviewer for a wide range of scientific journals.

The quality and impact of George's research, and that of his group, received considerable external recognition. This included several best paper awards from journals including ASHRAE, Biometeorology and JOSE, as well as awards recognising innovation in STEM and collaboration with industry. His wider recognition included the Chartered Institute of Ergonomics and Human Factors' Lifetime Achievement Award for Academic Research, the prestigious Bhattacharyya Award from the Royal Academy of Engineering and the honour of delivering the Buskirk Lecture at the American College of Sports Medicine.

Perhaps equally important was George's contribution to developing the next generation of researchers. As a supervisor and mentor, he was generous with his time and expertise, providing support and guidance while giving his students the freedom to develop their own ideas and interests. He successfully supervised 21 PhD students, many of whom went on to establish successful careers across applied physiology, medicine, design engineering and ergonomics, extending his influence well beyond his own research.

Professor Havenith's scientific legacy lies in showing how physiology, clothing and the environment interact dynamically. He developed individualised heat-strain models, transformed the measurement of clothing insulation and evaporative resistance, advanced our understanding of the burden imposed by protective clothing, pioneered sweat mapping and helped establish UTCI. His methods and equations informed international standards and influenced occupational safety, military procedures, sportswear and climate-health research.

George will be remembered as a world-renowned academic who approached all that he did with quiet humility, as a steadfast supporter of those who worked with him, and as a caring and proud family man. He is survived by his wife, Ria, and his children, Marlise and Bert.

Havenith, G., Heus, R., & Lotens, W. A. (1990). Clothing ventilation, vapour resistance and permeability index: changes due to posture, movement and wind. *Ergonomics*, *33*(8), 989–1005. https://doi.org/10.1080/00140139008925308

Havenith, G., Luttikholt, V.G.M. & Vrijkotte, T.G.M. (1995) The relative influence of body characteristics on humid heat stress response. *Eur J Appl Physiol* 70, 270–279. https://doi.org/10.1007/BF00238575

Havenith, G., (1999) Heat balance when wearing protective clothing, *The Annals of Occupational Hygiene*, Volume 43, Issue 5, July 1999, Pages 289–296, https://doi.org/10.1093/annhyg/43.5.289

Havenith, G., den Hartog, E., & Martini, S. (2011). Heat stress in chemical protective clothing: porosity and vapour resistance. *Ergonomics*, *54*(5), 497–507. https://doi.org/10.1080/00140139.2011.558638

Smith, C.J. and Havenith, G. (2012) 'Body mapping of sweating patterns in athletes: a sex comparison', *Medicine & Science in Sports & Exercise*, 44(12), pp. 2350-2361. doi:10.1249/MSS.0b013e318267b0c4.