

## Response to thermal stress and personality

J. LeBlanc<sup>a,\*</sup>, M.B. Ducharme<sup>b</sup>, L. Pasto<sup>b</sup>, M. Thompson<sup>b</sup>

<sup>a</sup>Department of Physiology, School of Medicine, Laval University, Quebec, Canada G1K 7P4

<sup>b</sup>Defense Research and Development Canada—Toronto, Toronto, Canada M3M 3B9

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### Abstract

Tolerance to cold and heat exposure shows large variations for which there is still insufficient explanation. On the other hand the relationship between the responses to mental stress and individual personality is well documented. The aim of this study was then to find if personality traits have some influence on the responses to environmental temperature exposure. A group of 20 young adults were exposed for 90 min to cold (10 °C) while skin temperature (Ts), oxygen consumption and discomfort rating were recorded. In a second experiment they were exposed to heat (40 °C) for 90 min when the sweat rate and the discomfort rating were recorded. Prior to these tests the Big Five Personality Test was used to measure the personality traits of the subjects. The results show significant negative correlation between neuroticism and the O<sub>2</sub> consumed, the discomfort rating and Ts for the test in the cold, while extraversion was positively related to O<sub>2</sub> consumption but not to Ts and discomfort rating. In response to heat, neuroticism predominance was associated with greater discomfort, reduced tolerance and diminished sweat rate. The discomfort rating, in this case, was negatively related to extraversion. It is proposed that the reduced O<sub>2</sub> consumption in the cold and the lower rate of sweating in the heat observed with neuroticism, are caused by enhanced activity of the sympathetic nervous system. Further investigation is required to assess the validity of this proposal. Overall, the present investigation shows that physical environmental stresses, in common with mental stress, could be in some ways related to personality traits.

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### 1. Introduction

During periods of low or high ambient temperatures, it is not uncommon to hear some people expressing more discomfort than others. That is for a given individual cold exposure could be as unpleasant an experience as heat exposure would be for another person. Indeed, large inter-individual variations have been reported in the responses to cold and heat, such as shivering intensity [37] and sweat production [14].

Many studies have tried to explain the large interindividual variability in the thermal responses of humans but to date none have provided a satisfactory explanation. With regard to the cold exposure, percentage body fat [9,27,33], surface area to mass ratio [1], fitness [26], age [26], gender [26] and adaptation [17–20,24–26] have all been used to explain some of the variability in the responses to cold.

However, as was mentioned in a recent study [37], no measured physical or physiological characteristic could fully explain the interindividual variability observed in shivering intensity during exposure to cold.

The present investigation is aimed at testing the following hypothesis: in addition to the known physical and physiological characteristics, the personality trait of an individual can influence his responses to thermal stress.

The Big Five Inventory (BFI) was used to identify the personality traits of the subjects. The BFI [2,4,10,16,30,32] and its related inventory [8,23] identifies the major components or dimensions of personality. Specifically, this test assesses the following five personality dimensions: extraversion, agreeableness, conscientiousness, neuroticism and openness. Extraversion includes traits such as sociability, dominance, and a tendency to be outgoing vs. reserved, aloof, shy, and solemn. The second factor, Agreeableness, is also interpersonal in nature and includes tendencies to be tolerant, cooperative, and warm vs. malicious, harsh, irritable, and insincere. Factor three, conscientiousness, refers to such traits as thoroughness, persistence, predictability, and de-

\* Corresponding author. Fax: +1-418-656-7898.

E-mail address: Jacques.LeBlanc@psh.ulaval.ca (J. LeBlanc).

pendability vs. carelessness, absent-mindedness, forgetful and erratic. Neuroticism refers to one's tendency to be anxious, fearful, sensitive, and self-critical vs. emotional resilience, calmness, stability, confidence, and independence. The final component is openness to experience and includes tendencies to be intellectually complex, insightful, original, curious, and studious vs. dull, illogical and narrow-minded.

## 2. Material and methods

### 2.1. Subjects

Twenty young healthy adults, 11 male and 9 female, ranging in age from 25 to 35 years participated in this study. The mean body fat, BMI, weight, and height for this group subjects were  $20.6 \pm 1.7\%$ ,  $23.4 \pm 0.6 \text{ kg/m}^2$ ,  $68.8 \pm 3.4 \text{ kg}$ , and  $170.8 \pm 2.8 \text{ cm}$ , respectively. They were given a small remuneration for each test. They were all informed about the protocol before signing the consent form. All procedures and forms used in this experiment were

reviewed and approved by the university experimental ethic committee.

#### 2.1.1. Personality measure (BFI)

Participants completed the Big Five Personality Inventory prior to exposure to heat and cold conditions. The Big Five Personality Inventory contains 44 statements designed to tap the five main dimension of personality [8,23,30]. Each statement contains response options ranging from 1 (*disagree strongly*) to 5 (*agree strongly*). Higher scores on each of the five scales are related to higher self-reported levels of extraversion, agreeableness, conscientiousness, neuroticism and openness.

#### 2.1.2. Exposure to cold ( $10^\circ\text{C}$ )

On the day of the experiment the subjects were asked to refrain from exercise and to take a light meal at 11:00 h. At 13:00 h the subjects sat for 30 min in a metabolic chamber maintained at  $26^\circ\text{C}$  for baseline measurement. At 13:30 h the subjects, wearing short and shirt, moved to an adjacent room kept at  $10^\circ\text{C}$  where they remained seated in the metabolic chamber for 90 min.

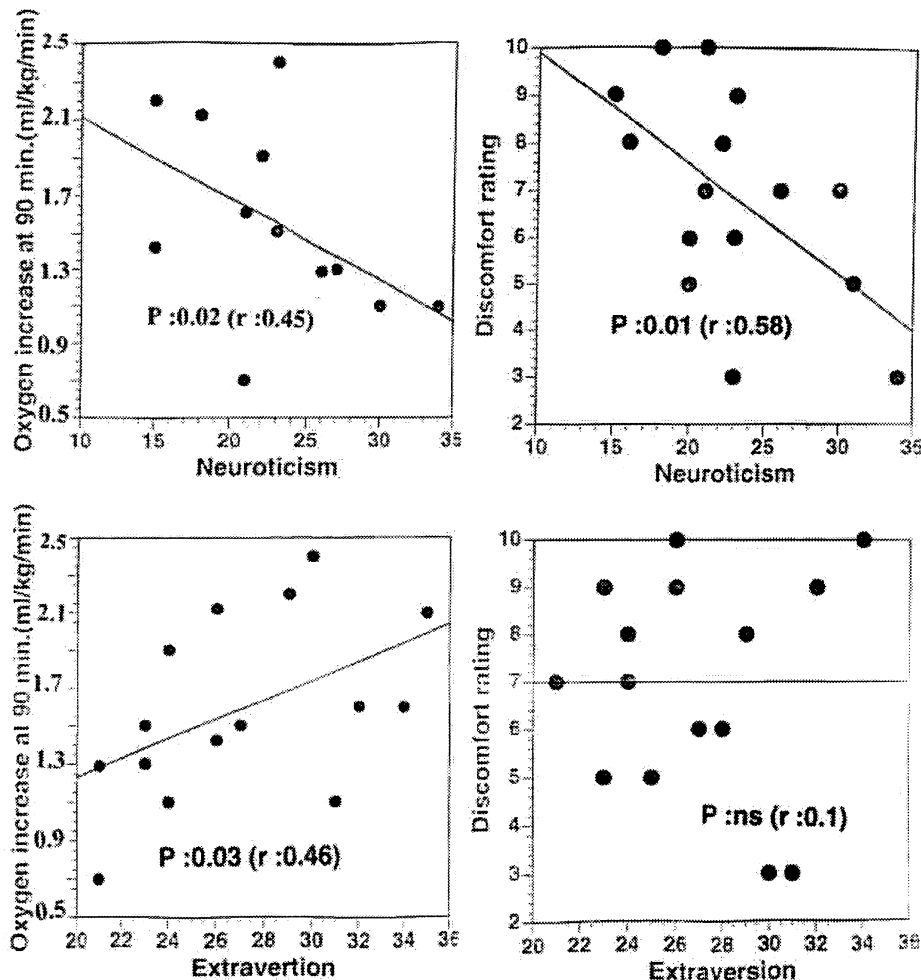


Fig. 1. Correlation between both extraversion and neuroticism, and the discomfort rating and oxygen consumption of subjects exposed to  $10^\circ\text{C}$  for 90 min.

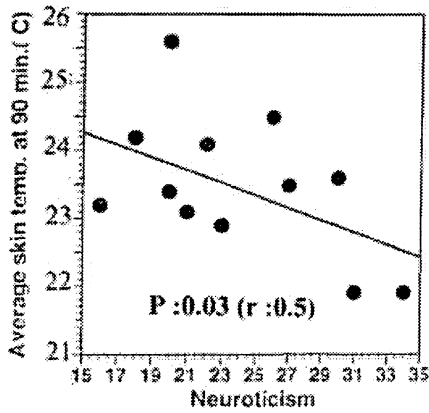


Fig. 2. Correlation between neuroticism and the average Ts in subjects exposed to cold (10 °C) at 90 min.

2.1.3. Exposure to heat (40 °C)

In this experiment, which took place approximately 1 week later, the subjects sat in a room at 40 °C for 90 min.

2.2. Methods

The skin temperatures (Ts) on forehead, chest, abdomen, upper back, thigh and leg, as well as rectal temper-

ature, were continuously recorded with thermistors. The formula described by Snellen [35] was used to calculate the average Ts when the subjects were exposed to cold. The rectal temperature was recorded from a thermistor inserted 10 cm into the rectum [Baxter Healthcare, Valencia, CA (400 series)]. Body mass index (BMI) was measured by dividing the body weight (kg) by the square of the height (m) [31]. The percentage of body fat was estimated by measuring the skinfold of various parts of the body (biceps, triceps, subscapular and suprailliac) with a caliper (John Bull, London) according to the method described by Jackson and Pollock [22]. A continuous flow of air was passed through a specially designed metabolic chamber having a 1.016 m<sup>3</sup> volume in which the subject sat during the cold experiment, while the O<sub>2</sub> consumed and the CO<sub>2</sub> produced were continuously recorded [28]. The results for the increase in oxygen consumption during the test were calculated by subtracting the values measured at time zero from those at 90 min. The increase in oxygen consumption in the cold is related to the shivering intensity experienced by the subjects. Sweat rate was measured by weighing the subjects before and after exposure to 40 °C with a scale having a 5 g resolution (Model Supercount, Setra System, Acton, MA, USA.) The difference between the two values indicated the total water lost due to heat

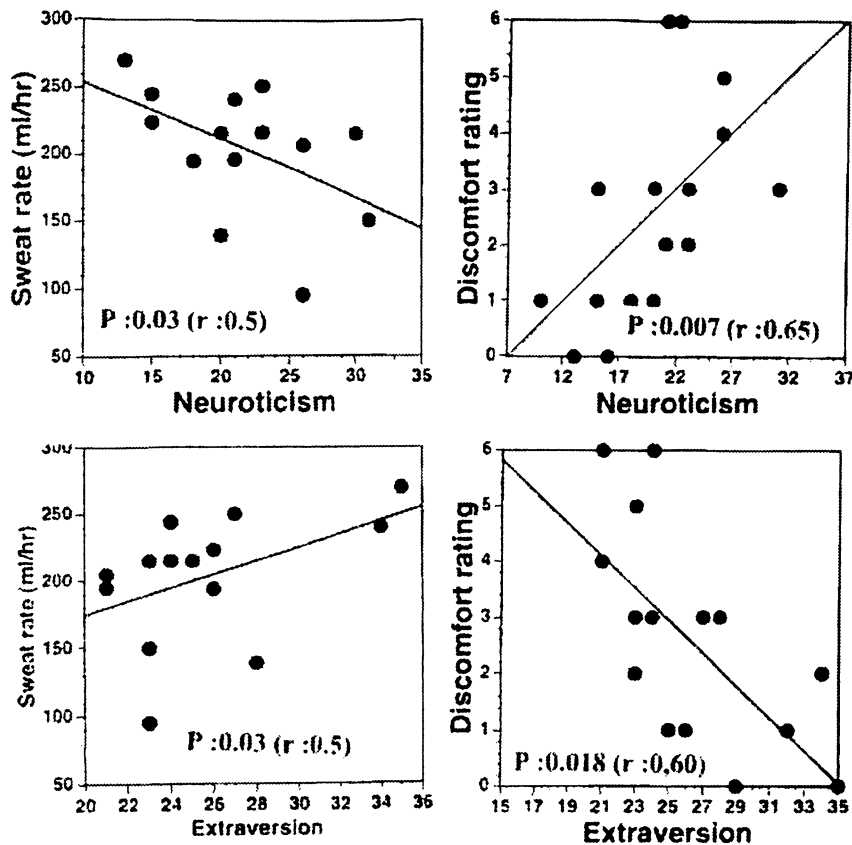


Fig. 3. Correlation between both extraversion and neuroticism, and the discomfort rating and sweat rate of subjects following exposure to 40 °C for 90 min.

exposure. At the end of both experiments the subjects rated the test using a scale ranging from 0 to 10 on which 0 would indicate *absence of discomfort*, while 5 indicated *moderate* and 10 *extreme discomfort*.

### 2.3. Statistical analysis

Regression analysis was used to relate the personality traits with each variable measured during exposure to cold and to heat. The nonparametric Wilcoxon test was used for the results obtained with rating and for the Big Five Test. Data are presented as means  $\pm$  standard error. The results are reported if they achieved level of significance of at least  $P < .05$ , except where otherwise indicated.

## 3. Results

The analysis of the results obtained with cold exposure indicates that neuroticism was significantly related to the results of the various measurements. The values for the increase oxygen consumed at 90 min, as well as the rating of discomfort in the cold are reported on Fig. 1. These two variables show a significant negative correlation when related to neuroticism, and a positive correlation between extraversion and the increase oxygen consumption at 90 min. Fig. 2 shows a negative interaction between neuroticism and the average Ts at the end of cold exposure. No significant correlation was found between the results of the various measurements and the other three personality traits. The statistical results for sweat rate and the rating of discomfort during exposure to 40 °C are presented in Fig. 3. Sweat rate showed a significant negative correlation with extraversion. On the other hand, discomfort rating showed a significant negative correlation with neuroticism and a positive correlation with extraversion. Fig. 4 shows that high level of extraversion is associated with low level of neuroticism. There was no indication of significant Ts change during the cold exposure.

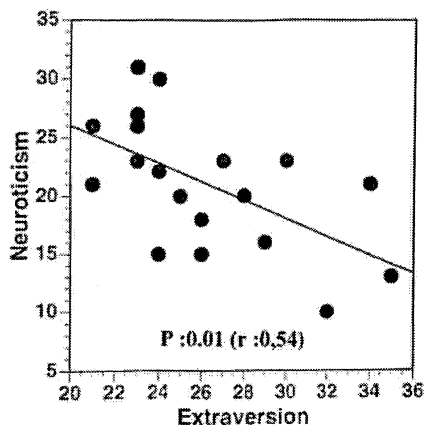


Fig. 4. Correlation between extraversion and neuroticism.

## 4. Discussion

This exploratory research suggests that certain personality traits may be differentially related to people's responses to warm and cold environment. More specifically, neuroticism was negatively correlated with the increase in oxygen consumption, the fall in mean Ts and the rating of discomfort during exposure to cold. Previous studies have shown that the level of shivering for a given cold exposure, is in part a function of the Ts. For example people with larger subcutaneous fat have lower Ts and shiver less when exposed to cold [9,27,33]. In the present investigation these findings were also observed with regard to neuroticism as shown on Fig. 2. At this point, the following question may be asked: "Why is it that a higher score of neuroticism is associated with lower Ts and a reduced shivering intensity during cold exposure?"

It has been shown that when the skin is cooled between 32 and 25 °C, the cold receptors show an increase in discharge activity [21]. However, at Ts lower than 25 °C, this action is reversed as the discharge activity is gradually reduced [9,11]. In view of the role of Ts in the control of heat production during exposure to cold [3,36], one can argue that at Ts lower than 25 °C, at a time when the activity of cold receptor is reduced, the shivering intensity will show a gradual decline. This was the case for subjects with greater subcutaneous fat who had lower Ts and reduced shivering intensity when exposed to cold [9,27,33]. The present investigation reports similar findings in subjects with higher neuroticism profile. In this case, however, the absence of correlation between neuroticism and the percentage of body fat indicates another mechanism. It is proposed that the lower Ts are due to enhanced vasoconstriction possibly caused by greater activity of the sympathetic nervous system. This possibility is supported by the fact that neurotics, by nature, are more often disturbed by and aroused in response of disruption in their daily activity [34]. It may be that upon exposure to cold, greater arousal of the autonomic nervous system (ANS) took place, which resulted in an additional drop in Ts. At present this hypothesis remains speculative. Future research in which measurements of sympathetic nervous system activity for individuals high and low in neuroticism is required to directly assess the validity of this proposal. In a sense, these findings indicate that neurotics are more subjectively distressed by the cold exposure but paradoxically, because of that, they respond less to this stress at a physiological level, as reflected by the level of shivering intensity. The implication could be that cold exposure for prolonged periods could lead to an earlier state of hypothermia in neurotics.

Rating of the heat test also showed some relation to subject personality. The discomfort rating during exposure to 40 °C was considered by the subjects as being light to moderate. In response to this stress, extraversion was found to be negatively related to discomfort rating. This

finding is in accord with other studies showing that the predominance of this personality trait predisposes to a more efficient coping with stress of moderate intensity [13,38]. On the other hand the relationship for neuroticism was negative for sweat rate and positive for discomfort rating. These findings are also somewhat expected for this personality trait. Indeed in this case, in the presence of day to day mental or physical stimulations, the arousal is typically somewhat exaggerated, in comparison with other traits, and as a result the ANS arousal is enhanced [8,12]. This arousal has been shown to increase skin resistance and to decrease conductance [30]. This being the case, it seems possible that the reduced sweating associated with neuroticism is related to an activation of the ANS. The fact that the rate of sweating is decreased and the rating of discomfort is increased with the predominance of neuroticism, may indicate a causal relationship between these two variables. Whether this defect is related to a central disturbance in the transmission of the signal for sweating or to a lack of activation of the cholinergic nerve fibers of the sweat glands is a question that deserves further investigation [5–7]. Walsh et al. [38] reported similar findings for a mental arithmetic test. They suggest that individuals high in neuroticism may have interpretative biases in the sense that they tend to amplify the rating of a stress in spite of a lower physiological response. In their investigation the challenge was a mental test that caused a smaller response in neurotic subjects, thus giving evidence of an improved defensive response. In the present investigation when dealing with a physical stress, such as exposure to heat, the rating was also amplified but the sweat response reduced. In this case, however, the lower rate of sweating would not prove to be beneficial. These findings suggest that neurotic individuals have developed a resistance in their physiological responses to threatening stimuli of mental [15] or physical origin as shown in the present study. As mentioned above it is not evident however that the rating of heat is biased. It is suggested that it may be related instead to a reduced sweating response. In all, this study on heat exposure indicates that the sweat rate, as well as the rating of heat discomfort, are related to personality, but further investigation is needed to understand the mechanism involved and to make conclusions concerning a causal relationship.

Overall, these results show that extraversion and neuroticism traits are differentially related to the various physiological parameters measured during exposure to heat and cold. This is corroborated by the negative relationship found between these two personality traits as reported on Fig. 4. A similar finding has been previously reported [29]. Taken together these studies indicate that the physiological responses and the subjective evaluation obtained following exposure to cold and to heat are in some ways related to personality traits. The various measurements relate primarily to the neuroticism trait. In this case the rate of sweating during exposure to heat is diminished and with cold expo-

sure, a reduction of shivering was observed. It is proposed that these alterations are caused by an enhanced activity of the ANS. Further investigation is required to assess the validity of this proposal.

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## References

- [1] Anderson GS. Human morphology and temperature regulation. *Int J Biometeorol* 1999;43:99–109.
- [2] Bartussek D, Becker G, Dirtrich O, Naumann E, Maier S. Extraversion, neuroticism, and event-related potentials in response to emotional stimuli. *Pers Individ Differ* 1996;20:301–12.
- [3] Benzingner TH. Heat regulation: homeostasis of central temperature in man. *Physiol Rev* 1969;49:671–759.
- [4] Borgatta EF. The structure of personality characteristics. *Behav Sci* 1964;9:8–17.
- [5] Candas V. Adaptation to extreme environment. In: Dejours P, editor. *Adaptations to extreme environment*. Basel: Karger; 1987. p. 72–6.
- [6] Chen WY, Elizondo RS. Peripheral modification of thermoregulatory function during heat acclimation. *J Appl Physiol* 1974;37:367–73.
- [7] Collins KJ, Crockford GW, Weiner JS. The local training effect of secretory activity on the response of eccrine sweat glands. *J Physiol (Lond.)* 1966;184:203–14.
- [8] Costa PT, McCrae RR. NEO PI-R Professional manual. Odessa (FL): Psychological Assessment Resources, Inc.; 1992.
- [9] Daniels F, Baker PT. Relationship between body fat and shivering in air at 10 °C. *J Appl Physiol* 1961;16:421–5.
- [10] Digman JM. Five robust trait dimensions: development, stability, utility. *J Pers* 1989;57:195–214.
- [11] Dykes RW. Cooling of steady and transient temperatures by cutaneous cold fibers. *Brain Res* 1975;98:485–500.
- [12] Eysenck HJ. *The biological basis of personality*. London: Routledge and Kegan Paul; 1967.
- [13] Eysenck HJ. General features of the model. In: Eysenck HJ, editor. *A model for personality*. Berlin: Springer; 1981.
- [14] Fox RH, Goldschmith R, Hampton LFG, Lewis HE. The nature of the sweating capacity produced by heat adaptation. *J Physiol (Lond.)* 1964;171:368–76.
- [15] Gold PW, Goodwin FK, Chrousos GP. Clinical and biochemical manifestations of depression. *N Engl J Med* 1988;319:413–20.
- [16] Goldberg LR. An alternative description of personality: The Big Five factor structure. *J Pers Soc Psychol* 1990;59:1216–29.
- [17] Hammel HT, Elsner RW, Lemessurier DH, Andersen HT, Milan FA. Thermal and metabolic responses of the Australian Aborigine to moderate cold in the summer. *J Appl Phys* 1959;14:605–15.
- [18] Hammel HT, Hildes JA, Jackson DC, Anderson DC. Thermal and metabolic responses of the Kalahari Bushmen to moderate cold exposure at night. Tech. Report No. 62-44. Arctic Aeromedical Laboratory, Ladd AFB; 1962.
- [19] Hammel HT, Hildes JA, Jackson DC, Anderson DC. Thermal and metabolic responses of the Alakaluf Indians to moderate cold exposure. Tech. Report No. 60-633. Wright Air Development Division; 1960.
- [20] Havenith G, Luttikholt VG, Vrijkotte TG. The relative influence of body characteristics on humid heat stress response. *Eur J Appl Physiol* 1995;70(3):270–9.

- [21] Hensel H, Iggo A. Analysis of cutaneous warm and cold fibres in primates. *Pflügers Arch* 1971;329:1–8.
- [22] Jackson AS, Pollock HL. Practical assessment of body composition. *Phys Sportsmed* 1985;13:76–90.
- [23] Johns OP. The “Big Five” factor taxonomy. In: Pervin LA, editor. *Handbook of personality: theory and research*. New York: Guildford Press; 1990. p. 66–100.
- [24] LeBlanc J, Pouliot M, Rheume S. Thermal balance and biogenic amine excretion in Gaspe fishermen exposed to cold. *J Appl Physiol* 1964;19:9–13.
- [25] LeBlanc J, Potvin P. Studies on habituation to cold pain. *Can J Physiol Pharmacol* 1966;44:287–94.
- [26] LeBlanc J. Adaptation of man to cold. In: Wang CH, Hudson JW, editors. *Strategies in cold*. San Diego: Academic Press; 1977. p. 595–715.
- [27] LeBlanc J. Subcutaneous fat and skin temperature. *Can J Biochem Physiol* 1954;32:354–9.
- [28] LeBlanc J, Cabanac M. Cephalic postprandial thermogenesis in human subjects. *Physiol Behav* 1989;46:479–82.
- [29] Mathews G, Dreary II. *Personality traits*. New York: Cambridge Univ. Press; 1998.
- [30] McCrae RR, John OP. An introduction to the five-factor model and its applications. *J Person* 1998;60:175–225.
- [31] Nieman DC. *Exercise testing and prescription*. Toronto: Mayfield Publishing; 1998.
- [32] Norman WT. Toward an adequate taxonomy of personality attributes. *J Abnorm Soc Psychol* 1963;66:574–83.
- [33] Rennie DW, Covino BG, Howell BJ, Song SH, Kand BS, Hong SK. Physical insulation of Korean diving women. *J Appl Physiol* 1966;17: 961–70.
- [34] Smith BD. Extroversion and electrodermal activity: arousability and the inverted U. *Pers Individ Differ* 1983;4:411–9.
- [35] Snellen JW. An improved estimation of mean body temperature using combined direct calorimetry and thermometry. *Eur J Appl Physiol* 2000;82:188–96.
- [36] Stolwijk JAJ, Hardy JD. Temperature regulation in man. *Pflügers Arch Gesamte Physiol Menschen Tiere* 1966;291:129–62.
- [37] Tikuisis P, Ducharme MB, Moroz D, Jacobs L. Physiological responses of exercised-fatigued individuals exposed to wet-cold conditions. *J Appl Physiol* 1999;86(4):1319–28.
- [38] Walsh JJ, Wilding JM, Eysenck MW. Stress responsivity: the role of individual differences. *Pers Individ Differ* 1994;16:385–94.