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Title: Decision making ability and thermoregulation in extreme environments during goal line official-like movement patterns

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Decision making ability and thermoregulation in extreme environments during goal line official-like movement patterns

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Abstract

Goal line officials (GLO) are exposed to extreme environmental conditions when employed to officiate in European cup competitions. Extreme environments have been shown previously to affect various facets of cognitive function. The present study aimed to investigate the effect of such environments on GLO. 13 male participants were exposed to 3 conditions, cold (-5 ^{o}C, 50% RH); temperate (18 ^{o}C, 50% RH); and hot (30 ^{o}C, 50% RH) for 90 minutes per condition, with a 15 minutes half time break after 45 minutes. Decision making ability was measured; using the Psyche Software Package, prior to each exposure (0 minutes), at the end of the first half (45 minutes), immediately after half time (45 minutes), and at the end of the second half (90 minutes). Exposure to cold conditions reduced positive stimuli responses (HIT scores) significantly when compared to hot conditions ($P<0.05$). Participants ability to track stimuli was also significantly reduced in cold conditions when compared to temperate and hot conditions ($P<0.05$). Reductions in decision making ability were coupled with reductions in physiological measures; cold exposure significantly reduced core temperature, skin temperature and thermal comfort when compared to temperate and hot conditions ($P<0.05$). The diminishment in GLO decision making ability during exposure to cold conditions, most notably the ability to respond positively to an infringement and the ability to track important stimuli, e.g. the football and goal line/player, are concerns which could negatively affect the outcome of a football match. Such findings should be considered by football's governing bodies when assessing the implementation of goal line technology and/or the continued use of GLO.

Declaration

I declare that this thesis is my own work. It is being submitted for the degree of MSc by Research at the University of Bedfordshire.

It has not been submitted for any degree or examination in any other University or educational institute.

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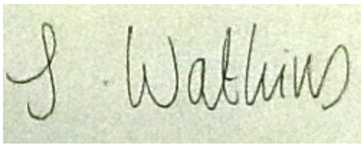
Candidate Signature: 

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Contents

1.0.Introduction

Association football match officials are employed to uphold the rules of the game and ensure that fixtures are played out in a fair manner. During a fixture match officials are required to make dozens of decisions, using data from the European Championship (2000) referees made 49 decisions per game on average including judgments on foul play infringements that may have lead to free kicks, penalties and red/yellow cards (Helsen and Bultynck, 2004b). During the same tournament linesman were required to make more decisions, 88 on average, these include judgements on throw ins, corners, goal kicks and goals scored (Helsen and Bultynck, 2004a). The judgements made on decisions in and around the penalty area such as, the awarding of goals and penalty kicks are deemed the most important made by match officials as they can decide the outcome of a match.

The judgements and decisions made by match officials suffer decrement during fatigue particularly during the second half of matches when referees cover 4.1% less distance than during the first half (Dottavio and Castagna, 2001). The effect on decision making performance is most noticeable on the 'game changing' judgements made within the penalty area. There are a number of examples of penalty area decisions incorrectly judged; i) Diego Maradona's goal versus England in the quarterfinal of the 1986 World Cup in which he scored with his hand, ii) Frank Lampard's disallowed goal versus Germany in the first knock-out stage of the World Cup 2010 and most recently, iii) Marko Devic's disallowed goal versus England during a group game of the European Championships 2012 which ultimately allowed England to progress to the knock out stages causing the Ukraine to be knocked out of the tournament.

Such mistakes lead to the call for the use of goal line technology to aid match officials in the judgement of goal mouth decisions, most importantly whether the ball has crossed the goal line. The International Federation of Association Football (FIFA) and The Union of European Football Associations (UEFA) opposed the use of goal line technology although many within the game including players and coaches were eager for its implementation. Amid growing pressure UEFA announced the use of Goal Line Officials (GLO) during all UEFA competitions to aid match officials in the penalty area judgments.

There is one GLO stationed next to each goal through the entire 90 minutes of a match. GLO can be consulted on infringements within the penalty area and indicate to the referee if the ball had crossed the goal line. UEFA competitions take place across Europe in varying environmental conditions, with fixtures being played out in conditions as cold as -10 ^{o}C (St. Petersberg, Russia; Rosenborg, Norway), and as hot as +30 ^{o}C (Madrid, Spain; Athens, Greece), exposing GLO to various environmental challenges.

Previously research has shown that exposure to extreme environmental conditions such as heat (Racinais, Gaoua et al. 2008; Simmons, Saxby et al. 2008), and cold (Makinen et al., 2006). Racinais et al (2008) report that exposure to hot conditions (50 ^{o}C, 50%RH) caused decrements in cognitive performance, including; increases negative responses (misses on a number sequence task), reductions in recall during a memory span task, and reductions in correct responses (match to sample and number sequence tasks) ($P<0.05$). Decrements were observed in comparison to heat exposure with head cooling, which appeared to ameliorate any heat induced decrement in cognitive task performance. A similar study carried out by Simmons et al (2008) compared the effects of passive heating (45 ^{o}C, 50%RH) to a head cooling condition. Simmons et al (2008) reports that the heat induced increase in core temperature reduced calmness, alterness and contentment during a battery of cognitive tasks (simple reaction time, 3 digit recognition task, and choice reaction time) ($P<0.05$). Similar decrements have been observed during cold exposure. Makinen et al (2006) observed significant ($P<0.05$) decrements in reaction time and information processing ability during repeated cold exposures (10^{o}C, 50%) compared to temperate conditions (25^{o}C, 50%RH).

Due to the nature of GLO movement patterns it is expected that exposure to cold conditions will affect cognitive performance significantly, where as exposure to hot conditions will be less detrimental. As GLO only make small lateral movements during a match it may be that their endogenous heat production may not be sufficient to offset the effects of the ambient environment during exposure to cold, altering physiology and cognitive functions negatively. Conversely during exposure to hot ambient conditions the lack of endogenous heat may be beneficial as it will minimise physiological and cognitive changes from that of temperate conditions.

The quantification of cognitive changes in GLO during exposure to different environmental conditions is of key importance, most notably to the debate of goal line technology; if it is the case that GLO are adversely effected by environmental conditions that are regularly experienced during UEFA competitions it would appear prudent to employ the use of ergogenic interventions to enhance cognitive performance during exposure to extreme conditions or introduce goal line technology which is not affected by the environment or natural human error.

Considering the outcome of previous incorrect goal line decisions that have effected teams' progression through major tournaments having both a social and financial impact it is crucial to assess the validity of GLO and their place in the professional game.

2.0.Literature Review

Match Referees and GLO: Their role within the game

Match officials ensure that matches are played out fairly and that the laws of the specific sport are abided to. Soccer match officials undergo more intense scrutiny than any other sport with regards to the decisions they make and the outcome such decisions have on the outcome of a match. On a weekly basis soccer match officials undergo scrutiny from the international media, i.e. television broadcasters and newspaper journalists. Match officials also receive advice, feedback and scrutiny from their peers and superiors within their respective referee association. The decisions made by match officials that receive the most intense focus are those in and around the penalty area: from the referee (Caballero et al., 2011), judgements of the awarding of penalties; and from linesmen (Catteeuw et al., 2009), judgements of whether goals are scored by players in an offside position/or not; and from both the referee and linesmen, whether the ball has crossed the goal line/or not (Catteeuw et al., 2009).

2.1.Importance of Decisions made in and around the Penalty Area

Judgements on infringements (decisions) made in and around the penalty area directly affect the outcome of a match, as they tend to affect the final score line. While decisions such as the awarding of penalties and whether a player is adjudged to be in an offside position/or not will always remain subjective and open to human error the judgement of whether the ball has crossed the goal line/or not could be made an objective judgement.

The original suggestion in ameliorating goal line mistakes was goal line technology that employs either cameras that monitor the goal line and can provide replays that can be quickly referred to in order to make a decision on whether the ball had crossed the goal line or not. Alternatively it was suggested that a microchip could be inserted into the ball that provides feedback to the match referee when the ball has crossed sensors that monitor the goal line indicating that the entire ball has crossed all of the goal line.

While these suggestions appear sensible in objectifying the issue of whether the ball has crossed the goal line/or not it received significant resistance from Fédération Internationale de Football Association (FIFA) and the Union of European Football Associations (UEFA) the two most influential and powerful corporate bodies within world soccer.

2.2.International Nature of UEFA Competitions

Following high profile incidents of goals incorrectly not being awarded , recently Frank Lampard's 'goal' versus Germany during the first knock out round of the World Cup 2010, which subsequently lead to England losing the match and being knocked out of the tournament famous figures within the sport called for the implementation of goal line technology. In response UEFA employed *Goal Line Officials* (GLO), GLO were appointed to aid in referees and linesmen in the judgement of decisions and infringements within the penalty area, most notably judgement of whether the ball has crossed the goal line. One GLO is situated to the side of each goal, as such GLO are not required to move and remain static for the entire match.As GLO are only employed by UEFA they are only used in UEFA Cup Competitions, such as the UEFA Champions League and the UEFA Europa League. These competitions include teams from all areas of Europe, i.e. Scandinavia, Eastern Europe, The Baltic States, The Mediterranean, Mainland Europe and The United Kingdom. Such widespread inclusion means that match officials; referees, linemen, and GLO are subjected to varying environmental conditions and depending on the time of year possible extreme ambient conditions, for example Rosenberg (-10 ^{o}C) or Madrid (+ 30 ^{o}C). While the effects of such conditions have been investigated on the physical and cognitive performance of active sports people and referees the effects of these ambient extremes have not been investigated in static participants with similar movement patterns to GLO, and thus the effects of these conditions on the decision making performance of GLO in particular are unknown. As previous literature has reported detrimental effects of varying ambient extremes on the cognitive, decision making performance of humans it would seem prudent to investigate the effects of varying ambient conditions, which are experienced in UEFA competitions, on the decision making ability of GLO, as the decisions they make directly affect the outcome of matches.

2.3.Decision making and cognitive function in temperate conditions

Although extreme ambient conditions are experienced in UEFA Cup Competitions conditions not all fixtures take place in hostile environments; with some matches being played out in comfortable, temperate conditions. Areas of Europe such as the United Kingdom rarely experience ambient extremes and tend to have stable conditions through the soccer season, with temperatures rarely exceeding 10 ^{o}C – 20 ^{o}C (MetOffice, 2012a) at either end of the scale.

Such conditions are not extreme enough and should not impose a significant enough physiological strain to effect either physical or cognitive performance of match officials. In turn, this should then result in referees, linesmen and GLO judging the majority of the decisions they are required to make correctly. Previous research reinforces these hypothecations (Cian et al., 2001, McMorris et al., 2006, McMorris and Graydon, 1997, Simmons et al., 2008a). Such studies comparing comfortable (normothermic) environmental conditions to environmental extremes found physical and cognitive performance were significantly better in the comfortable conditions. Throughout the proceeding sections effects of environmental extremes will be compared to normothermic conditions, all of which are experienced in UEFA Cup Competitions.

2.4.Decision making and cognitive function in cold

The group stages and early knock out rounds of UEFA competitions take place during the European winter. Throughout the European winter large areas of the continent suffer sub-zero temperatures of which match officials are subject to during cup fixtures. These cold conditions will affect the various match officials differently and this must be considered. As referees are constantly exercising during a 90 minute match their metabolic heat production will increase considerably from rest and maintain endogenous temperatures at desirable levels (Doubt, 1991). As referees' endogenous temperatures do not suffer decrement during cold exposure their cognitive and physical performance should undergo minimal reductions. Conversely the relationship between cold ambient conditions and GLO performance is much more complex.

Although exposure to extremely cold ambient conditions can be as detrimental to human performance as heat exposure much less research has investigated its negative effects. As continuous exercise offsets cold induced cognitive decrement sport science research has tended not to focus upon the effects of cold conditions on human performance. GLO pose a unique issue within sport as they are static throughout a 90 minute match and thus their metabolic heat production is minimal making them susceptible to the detrimental effects of cold exposure, particularly reductions in cognitive performance, which is essential for GLO.

The existing literature (Adam et al., 2008, Doubt, 1991, Mahoney et al., 2007, Makinen et al., 2006) investigating the effects of cold exposure on cognitive performance has been unanimous in reporting the decrement observed in cognitive function during cold exposure. The existent research although observing significant decrements in cognitive function during cold exposure fails to measure or suggest the physiological alterations, especially within the brain, that cause the cognitive decrements observed. The only proposed suggestion to date is that exposure to environmental stress up-regulates the usage of neurotransmitters (central catecholamines) dopamine, norepinephrine and epinephrine by non-cognitive processes which reduces the availability of neurotransmitters within the prefrontal cortex which is responsible for decision making (O'Brien et al., 2007a).

2.5.Metabolic Rate

The metabolic turnover of GLO during a match will be close to resting levels as they are not required to exercise. Low metabolic turnover during exposure to cold conditions may serve to be detrimental as little metabolic heat will be produced which is beneficial in maintaining endogenous temperatures during cold exposure; making GLO susceptible to the negative effects of cold ambient environments. Furthermore metabolic rate is temperature dependant and so may suffer functioning decrements when endogenous are reduced during cold exposure.

Metabolic rate is a broad term that encompasses numerous levels of energy turnover and heat production. The well understood term *standard metabolic rate*, also known as resting metabolic rate is what is generally referred to as metabolic rate. To achieve standard metabolic rate one must be; awake, resting and not digesting (Rolfe and Brown, 1997). Moreover, to attain a steady standard metabolic rate, one must not be exposed to adverse environmental conditions, thus thermoregulatory response is not activated (Porter et al., 1999).

Resting (standard) metabolic rate is a direct measure of the expenditure of survival (Clarke, 2004). Metabolic rate; both basal and resting have received intense focus throughout the last century. Previous literature has worked towards elucidating on the temperature dependence of metabolism (Clarke, 2004, Clarke and Fraser, 2004). Metabolism and temperature form a symbiant cycle, with one directly affecting the other.

2.5.1. Temperature Dependence of Metabolic Rate

Metabolism is reliant on temperature. Biochemical reactions required to sustain life are temperature dependant. Metabolic rate can be explained using a simple, elegant equation:

$$\mathrm{B} = E_{\mathrm{i}} R_{\mathrm{i}}$$

B represents metabolic rate. Ei is activation energy; energy potential required to begin a chemical reaction. Ri represents the energy output produced by the biochemical reactions that constitute metabolism. The rate of energy production (output) is dependant on 3 factors: *concentration of reactant*; *fluxes of reactants*; *kinetic energy of the system* (Gillooly et al., 2001).

Concentration of reactant and fluxes of reactant are reliant on ones body mass and substrate availability (Clarke et al., 2010). In the absence of vital reactants the necessary reactions cannot be actioned, thus metabolism becomes inefficient, and is suppressed (Clarke and Fraser, 2004). An example of this is starvation; starvation explains a lack of energy intake, reducing reactant availability, slowing metabolism. The substrate dependence of *concentration of reactant* and *fluxes of reactant* means that they are body mass dependant (Gillooly et al., 2001).

However, *kinetic energy of system,* unlike the previous factors is not body mass dependant but temperature dependant. Temperature dependence of a reaction is governed by the Boltzmann Factor (Gillooly et al., 2001);

$$e^{-E\mathrm{i}/k\mathrm{T}}$$

Where Ei is the activation energy, the energy potential required to begin a chemical reaction. K is Boltzmann's constant; this explains that the potential energy within a molecule is directly linked to the absolute temperature. So, an increase in temperature increases energy potential. Finally T represents temperature. Collectively Boltzmann's factor explains the temperature dependence of any chemical reaction (Gillooly et al., 2001).

The above mentioned equation, $B=E_iR_{I}$,, although simple and appears to explain the facets involved in metabolic rate it fails to account for the variance in body mass and temperature requirements of a specific species. As previously mention R_i relies on substrate availability and is temperature dependant.

As GLO are exposed to cold conditions throughout a large duration of UEFA club cup competitions they will suffer reductions in endogenous temperatures. Reductions in endogenous temperatures (core temperature, skin temperature and muscle temperature) lead to a reduction in molecule temperature and thus reduce its energy potential; suppressing its function efficiency (Clarke et al., 2010). Should these molecules be located in key areas of the body i.e. the brain or central nervous significant reductions in vital physiological and cognitive functions may be observed.

2.5.2. Metabolic Rate, the Brain and Decision Making

GLO are required to make match changing decisions that may ultimately effect the outcome of a fixture. Should the interaction between cold conditions and alterations in metabolic rate affect physiological functions, in particular cerebral functions, then the performance of GLO may suffer significant decrement.

Humans possess a larger brain to body mass ratio than that of any other animal, this is termed as encephalization (large brain: body mass) (Cools, 2008). It is this enlargement that allows for the execution of complex cognitive processing such as the executive functions carried out by the prefrontal cortex (Cohen et al., 2002). Such an advanced brain comes at a large metabolic cost; humans contribute around 20-25% of total resting metabolic energy expenditure to brain functioning (Leonard et al., 2007). For a comparison cerebral and neural tissues required 16 times more energy (kcal/g/min) than muscular tissue, even so humans do not have a higher resting metabolic rate than any other organism of the same size (Leonard et al., 2007).

A consequence of the human brains high energy cost is that the body must ‘sacrifice’ energy elsewhere in order to provide the brain with sufficient calories. This evolutionary adaptation is most noticeable when comparing humans to other primates. Humans have a lower muscle mass and higher fat mass compared to other primates in respect to their total body mass. The energy saved from a reduction in muscle mass increases the available calorific contribution to the brain allowing for optimal functioning (Leonard et al., 2007). The higher fat mass possessed by humans is also an evolutionary adaptation beneficial to cerebral metabolism, fat has a lower energy cost than that of muscle, but also acts of a source of energy when other stores are depleted, during either bouts of intense exercise or in an evolutionary sense starvation (Leonard et al., 2007).

The reduction in muscle mass may also have a significant effect on thermoregulatory response especially during exposure to cold conditions. Shivering thermogenesis requires muscular contraction to produce heat (Nakamura and Morrison, 2011). Muscular contractions are only 20-25% efficient, meaning that 75-80% of the energy supplied for contraction is lost as a by product; predominantly heat (Haman, 2006). Thus during exposure to cold humans activate shivering thermogenesis in order to benefit from the heat created as a by product. Because humans have reduced their total muscle mass in order to supply the brain with the energy required a decrement in heat producing capacity during exposure to the cold may manifest as a trade off(Foley and Fleshner, 2008). So it would appear that evolution has favoured the functioning of the brain to the need to stay warm during exposure to the cold. But, an alternative line of thought may counter this theory; the increase in human fat mass. Within the literature it is not clearly stated as to the type of fat that increased over time in comparison to muscle mass, although it seems rational to presume that there was a relative increase in both white and brown adipose. During exposure to cold conditions white adipose tissue would act simply as an insulator to the cold preserving any heat produced within the core maintaining the integrity of all vital organs. Whereas brown adipose tissue (non-shivering thermogenesis) is heat producing, uncoupling the oxidative phosphorylation process from ATP synthesis to heat production (Virtanen and Nuutila, 2011). Although it seems unlikely that muscle was traded off for brown adipose tissue as the process of non-shivering thermogenesis is extremely energy inefficient and would counteract the propose of muscle mass reduction.

It would appear prudent to also consider the effects of environmental changes, especially ambient temperature, on the metabolic turnover and cost of the brain. The brains calorific requirements, as stated earlier, are extremely high during exposure to comfortable conditions, so it seems rational to predict that during exposure to heat and cold the brains energy demands will only increase. If we then consider the functions the brain requires energy to perform in ambient conditions; motor control, information processing, response control/inhibition, executive functioning, hormonal control to name only a few (MISSALE et al., 1998). These processes all require considerable cerebral space to function consuming large amounts of energy (Savitz et al., 2006). If for example we consider the additional processes activated during exposure to environmental stress, cold for example; additional sensory information must be processed, regarding endogenous temperatures, responses must then be actioned; including shivering thermogenesis, non-shivering thermogenesis, and vasoconstriction (Bligh, 2006). All three responses have substantial energetic requirements, consuming vast amounts of the neurotransmitter norepinephrine (Nakamura and Morrison, 2008b). The increase in metabolic rate experienced during exposure to the cold will in part be due to the additional requirements of the thermoregulatory systems activated to reduce the effects of the environment (Mäkinen et al., 2001). Thus, humans should show considerable attention to nutrition prior to cold exposure to ensure they have consumed sufficient calories to allow all functions and responses to work optimally. Should ones concentration of particular substrates be insufficient processes may be sacrificed, for example, should levels of norepinephrine become depleted neural projections of norepinephrine used to activate thermoregulatory responses will be prioritised over cerebral projections of norepinephrine used by the prefrontal cortex for cognitive functions such as concentration, attention, decision making, and reasoning (Harmer et al., 2001).

The interaction between ambient temperature, the brain, and physiological responses is complex. Various trade-offs may occur which tend to favour survival and thus the activation of thermoregulatory responses and to the detriment of cognitive processes. The considerable metabolic requirement of the brain means that cold induced interruptions to metabolic rate and prioritisation of thermoregulatory responses may lead to GLO making more officiating errors during cold exposure which may negatively affect the outcome of a fixture.

2.6.Physiological Responses to Extreme Environments

2.6.1. Cold Exposure

As GLO will undergo considerable endogenous temperature change during exposure to cold conditions thermoregulatory responses must be activated in an attempt to maintain endogenous temperatures at a safe level. Such thermoregulatory responses require norepinephrine to function; during cold exposure these responses are prioritised over prefrontal functioning responsible for higher cognitive processes which also require norepinephrine. As these thermoregulatory responses may considerably effect the decision making performance of GLO it is important to understand their processing.

2.6.1.1. Skin blood flow

Vasoconstriction is a thermoregulatory response to cold exposure. Vasoconstriction occurs during both local cooling of the skin and whole body cooling (Charkoudian, 2010). Vasoconstriction is induced by more than one pathway:

2.6.1.2. Nitric Oxide

The availability of nitric oxide (NO) affects both vasodilation and vasoconstriction. If NO is readily available then it aids in the process of vasodilation, an important mechanism in the thermoregulatory homeostasis of heat exposure. Conversely, the inhibition of NO allows vasoconstriction to ensue. Previous research (Johnson and Kellogg, 2010, Kellogg, 2006, Kellogg et al., 2009) demonstrates that vasoconstriction is not possible in the presence of NO, with (Kellogg, 2006) reporting successful vasoconstriction when NO is artificially inhibited with N^{G}-nitro-L-arginine (L-NAME), without cooling. Kellogg (2006) then compared skin blood flow at two separate sites: one site treated with L-NAME, and no treatment at the other site; both sites were exposed to local cooling. L-NAME induced vasoconstriction immediately after prescription, with a slower vasoconstrictory response at the cooling-only site. Importantly at the end of the local cooling protocol both conditions displayed similar, minimal skin blood flow. Although the substance response for NO inhibition in vivo is unknown (Kellogg et al., 2009).

2.6.1.3. Rho Kinase

Rho kinase, a GTPase, aids in the vasoconstriction of smooth muscle cells (blood vessels), via two pathways (Somlyo and Somlyo, 2000). Myosin phosphatase inhibits cellular contraction by dephosphorylating myosin light chains, which phosphorylates myosin of the cross-bridge cycle, reducing contractile potential (Wettschureck and Offermanns, 2002). During bouts of myosin phosphate regulation smooth muscle cells are in a relaxed state, when contraction is required Rho kinase is activated. Rho Kinase acts upon the myosin sub unit (a sub unit of myosin phosphatase. The myosin sub unit is phosphorylated by Rho kinase, thus inhibiting myosin phosphatase (Wettschureck and Offermanns, 2002). The inhibition of myosin phosphatase allows the phosphorylation of myosin light chains, leading vasoconstriction through smooth muscle contraction (Wettschureck and Offermanns, 2002).

2.6.1.4. Brown Adipose Tissue

On a reduction in body temperature brown adipocytes receive signals via the sympathetic nervous system (CANNON and NEDERGAARD, 2004). This signal transmission initiates the release of norepinephrine (NE), which activates the thermogenic action of brown adipose tissue

(BAT) (CANNON and NEDERGAARD, 2004). The activeation of BAT begins with NE binding to a B3 adrenergic receptor, this initiates a signalling cascade(CANNON and NEDERGAARD, 2004), as described in figure 1.

B3 Adrenergic Receptor

Stimulatory G Protein

Adenylyl Cyclase

cAMP

Protein Kinase A

Figure 1. The cascade begins with signal transduction from B3 adrenergic receptor to stimulatory G protein (G3). G3 is response for initiating the production of cyclic adenosine monophosphate (cAMP) via adenylyl cyclase (CANNON and NEDERGAARD, 2004, Lowell and Spiegelman, 2000). cAMP is a secondary messenger, which in the present pathway activates protein kinase A (PKA).

PKA has a duel role within the present pathway, to explain both roles it is beneficial to elucidate on what happens beyond the next cascade stage (refer to Figure 2.).

PKA

Phosphorylation of perilipin   Hormone Sensitive Lipase

Triglyceride Droplet

Figure 2. Describes the lipolysis activation stage. In which hormone sensitive lipase (HSL) is activated via PKA (CANNON and NEDERGAARD, 2004, Lowell and Spiegelman, 2000). HSL is necessary for the breakdown of triglycerides (TG) into free fatty acids (FFA). Yet, PKA must first act upon TG before HSL can begin activate lipolysis (CANNON and NEDERGAARD, 2004). Triglyceride contains perilipin, perilipin protects TG against HSL's ability to catabolise lipids . Thus, PKA seperates perilipin from TG via phosphorylation, allowing HSL to begin lipolysis.

HSL has now hydrolysed TG into FFA. FFA cannot permeate the inner mitochondrial membrane, and so they are converted to acyl-CoA via acyl-CoA synthase (Lowell and Spiegelman, 2000). Acyl-CoA is the converted to acyl-carnitine via carnitine palmitoyltransferase (Lowell and Spiegelman, 2000). A carnitine catalyst then transports acyl-carnitine across the inner mitochondrial membrane to commence beta-oxidation (CANNON and NEDERGAARD, 2004).

Beta oxidation results in NADH and FADH production (with further contribution from the cyclic acid cycle). NADH and FADH are them sent to the electron transport chain (ETC), where they undergo oxidisation. The resulting product of the ETC is hydrogen which is released from the mitochondria via the ETC's complex's I, III, & IV (Lowell and Spiegelman, 2000).

The shifting of hydrogen from within the mitochondria creates an electrochemical potential gradient. Hydrogen may then re-enter the mitochondria through 1 of 2 pathways: Firstly, via the F_0/F_1ATPase, in which ATP is produced using hydrogen, ADP & Pi (Lowell and Spiegelman, 2000). Alternatively hydrogen can re-enter the mitochondria via uncoupling protein 1 (UPC1) (Lowell and Spiegelman, 2000). This allows hydrogen to pass the mitochondrial membrane in the absence of F_0/F_1ATPase, this process creates energy but is released as heat and not ATP(CANNON and NEDERGAARD, 2004, Lowell and Spiegelman, 2000). UCP1 makes the transfer of hydrogen across the mitochondrial membrane possible by dissipating the difference between the inner and outer mitochondrial gradient (CANNON and NEDERGAARD, 2004).It is important to note that UPC1 is not activated when FFA are not present. The production of heat aids in the maintenance of endogenous heat, retaining physiological integrity.

2.6.1.5. Shivering

Perhaps the most easily visible response to ambient cold exposure is shivering. Shivering aims to increase metabolic heat production via the energy inefficiency of the cross bridge cycle (Nakamura and Morrison, 2011, Haman, 2006). Shivering is a 'last resort' mechanism not activated until endogenous temperatures are a degree (ºC) lower than that required to activate vasoconstriction (Sessler, 2009). The signalling pathway which transfers thermo-sensory information from the skins thermo-receptors to brain and a resultant thermoregulatory has only recently been elucidated (Sessler, 2009) in a number of recent papers (Morrison et al., 2008, Nakamura and Morrison, 2008a, Nakamura and Morrison, 2011, Nakamura and Morrison, 2007). Although it is important to note much of this work is carried out on rodents and not humans.

The signalling pathway is complex and involves many stages, the first of which involves the sensing of environmental cold through a reduction in skin temperature (Nakamura and

Morrison, 2011). External cold is sensed by the skin thermo-sensors, with the informative signal sent to the dorsal horn which is located on the dorsal (back) of the spinal cord (grey matter section) (Nakamura and Morrison, 2008a). The signal is then projected to the lateral parabrachial nucleus, which is located within the Pons area of the brain (Morrison et al., 2008, Nakamura and Morrison, 2008a). The signal is then relayed to the median preoptic subregion of the preoptic area (MnPO) via glutamate neurotransmitters, where the signal is received by glutamate receptors (Nakamura and Morrison, 2011, Nakamura and Morrison, 2008a). On receiving the thermo-sensory signal the MnPO releases GABAergic interneurons, these are inhibitory neurons (Nakamura and Morrison, 2008a, Nakamura and Morrison, 2011). The GABAergic interneurons inhibit the GABAergic neurons of the medial preoptic area (MPO) (Nakamura and Morrison, 2011, Nakamura and Morrison, 2008a). During normothermic conditions the GABAergic neurons of the MPO enforce an inhibitory effect upon the excitatory pathway which is responsible for thermoregulatory response (Nakamura and Morrison, 2011, Nakamura and Morrison, 2008a). During cold exposure the MPO's GABAergic neurons are inhibited (by the MnPO's GABAergic interneurons) and so thermoregulatory response is disinhibited (Nakamura and Morrison, 2011, Nakamura and Morrison, 2008a). The dorsomedial hypothalamus is now free to activate neurons which exist within the rostral raphe pallidus nucleus (rRPa) (Nakamura and Morrison, 2011, Nakamura and Morrison, 2008a). Neurons from the rRPa act upon the ventral horn of the spinal cord (anterior, grey matter section) (Nakamura and Morrison, 2011). The ventral horn is responsible from muscle excitation, via the instigation of neuronal motor recruitment. The ventral horn signals to the muscle to rapidly contract, causing shivering (Nakamura and Morrison, 2011).

During cold exposure the previous mechanisms will be activated in order to maintain endogenous temperatures which should aid in maintaining physiological integrity. Although such mechanisms are designed to improve the chances of survival during cold exposure they appear to have a negative effect on cognitive performance (Makinen et al., 2006). This trade off may lead to significant reductions in GLO performance.

2.6.2. Heat Exposure

As the latter stages of UEFA club cup competitions at played out in the late European spring and international UEFA competitions are competed during the European winter GLO are exposed to hot ambient conditions on a regularly. During heat exposure thermoregulatory responses are activated in order to maintain thermoregulatory homeostasis, and in turn should maintain human performance.

2.6.2.1. Heat Exchange

The mechanisms encompassing heat exchange from within the body to the external environment are grouped into two categories, *Dry:* radiation, conduction and convection; and *Wet:* evaporation (Cheung et al., 2000).

Dry heat exchange is reliant on there being a differing temperature gradient between the core and shell temperatures of the body, as well as a gradient between the body as a whole and the environment. Subsequently, should there be a lack of temperature between the afore mentioned facets involved heat exchange cannot take place (Campbell, 2008).

Wet heat exchange is mediated by the water vapour pressure gradient between the body surface and the external environment (Cheung et al., 2000). Subsequently evaporative heat loss is affected by the humidity of the external environment with high levels of humidity significantly reducing evaporative heat loss potential (Cheung et al., 2000)

$$Ereq = M - W \pm (C + R + K) \pm (C_{resp} - E_{resp})$$

Figure 3. The required rate of evaporative cooling required to mediate heat loss taking.

Figure 3. explains the rate of heat loss required from evaporation to balance all other sources of heat gain and heat loss, where M is metabolic rate, W is the rate of heat loss generated from external power, R, C, and K represent radiation, conduction and convection (Bain et al., 2012). C_{resp} is the conductive heat transfer through respiration and E_{resp} is the evaporative heat transfer from respiration (Bain et al., 2012).

2.6.2.2. Conduction

Conduction is the process of heat migrating from one surface to another during contact. Similarly to diffusion heat is transferred from a surface of high temperature to a surface of a lower temperature. During exposure to heat conduction provides the smallest contribution to endogenous heat loss, approximately 3% (Kenny Gp Fau - Journeay and Journeay).

2.6.2.3. Convection

Convection relies on cool air passing over the surface of the skin as a means of heat removal. Convection contributes approximately 15% to total heat dissipation. Convection is most effective when one is outside exposed to the wind, but convection can be artificially employed using fans (Charkoudian, 2003).

2.6.2.4. Radiation

Radiation is the largest contributor to endogenous heat dissipation, providing 60% of ones heat loss. Radiation describes the transfer of heat from the body to the environment via infra red rays. Its worth noting endogenous infra red ray expulsion is in constant competition with external infra red ray absorption from the environment, compromising the efficiency of radiation heat loss (Charkoudian, 2003).

2.6.2.5.Evaporation

Evaporation describes the dissipation of heat through sweating and ventilation. Ambient humidity plays a crucial role in evaporation, environments in which the humidity is high will be reduce evaporation capacity, unlike areas of low humidity in which evaporation more efficient. At rest in comfortable conditions evaporation contributes 20% to heat dissipation, but during exercise and exposure to hot conditions evaporation's contribution can rise to as much as 80% (Charkoudian, 2003).

2.6.2.6. Skin Blood Flow

Vasodilation plays a key role in the homeostasis of endogenous temperatures, especially during exposure to the heat. Many vasodilation activators have been proposed previously, with on going research still attempting to elucidate further on the substance accountable for vasodilation. Here a short review of the possible activators is provided:

2.6.2.7. Nitric oxide

The synthesis of nitric oxide (NO) begins in the endothelial cells, which are located on the inner lining of blood vessels. Other cells and tissues contribute to NO production although endothelial synthesis is dominant (Lowenstein et al., 1994, Joyner and Dietz, 1997).

The signalling pathway for the production of NO begins with acetylcholine. Acetylcholine binds with its transmembrane receptor located next to the lumen (Joyner and Dietz, 1997). This binding exponentially increases levels of calcium within the cell, which bind to calmodulin. Calmodulin is a messenger protein, responsible for the transduction of calcium's signal to the next receptor(Joyner and Dietz, 1997, Lowenstein et al., 1994). The transduction activates NO synthase, an enzyme responsible for the synthesis of NO. NO synthase is then coupled with arginine and oxygen to produce NO (Lowenstein et al., 1994).

NO then migrates from the endothelial cell to a nearby smooth muscle cell, where it binds to iron and guanylate cyclise (GC). On binding to GC, GC's dephosphorylating potential is activated, converting guanosine triphosphate into cyclic guanosine monophosphate (cGMP) (Lowenstein et al., 1994).

There are various mechanisms suggested as to how cGMP causes vasodilation, they include; a reduction in calcium migration into smooth muscle cells, reducing contractile potential. cGMP may also reduce a cells membrane potential by activating ion channels, leading to hyperpolarization. Finally it is suggested cGMP may aid in the in the activation of myosin light sub units, reduce the phosphyorlation of myosin II by dephosphorlyating myosin light chains (Lowenstein et al., 1994).

2.6.2.8. Vasoactive intenstinal petitde (VIP)

Similarly to nitric oxide, vasoactive intestinal petitide (VIP) activates cGMP as a means of relaxing smooth muscle cells (Petkov et al., 2003). VIP has the ability to bind to two receptors: vasoactive intestinal polypeptide 1 (VPAC-1) and vasoactive intestinal polypeptide 2 (VPAC-2), both are located on the subintima of peripheral blood vessels. On activation of these receptors the cGMP system is activated and follows the same pathway following activation via NO (Petkov et al., 2003).

Other substances such substance P and histamine have been shown to contribute to the vasodilation of blood vessels but to a lesser extent than that of VIP and most notably NO.

2.6.2.9. Heat Tolerance- Individual Differences

An individual's ability to deal with various environmental conditions is dependent upon a plethora of individual characteristics. An individual's anatomical make up can have a significant effect on how one can deal with environmental stress and the effects of such conditions on physical and cognitive performance (Havenith, 2001). A well established model for the modulators and effectors of ones ability to deal with environmental stress was proposed by Havenith et al. (2001). This individualised model describes the body's physiological interaction with different environmental conditions. The model outlines the physiological mechanisms that are effected by inter-individual differences in physiological make up, for example; fat and fat percentage has a direct effect on the core and skin temperature (Havenith, 2001). Individual differences such as body fat percentage, total body surface area, fat free mass and aerobic fitness will alter how a person will respond to hot and cold exposure (Schlader et al., 2010).

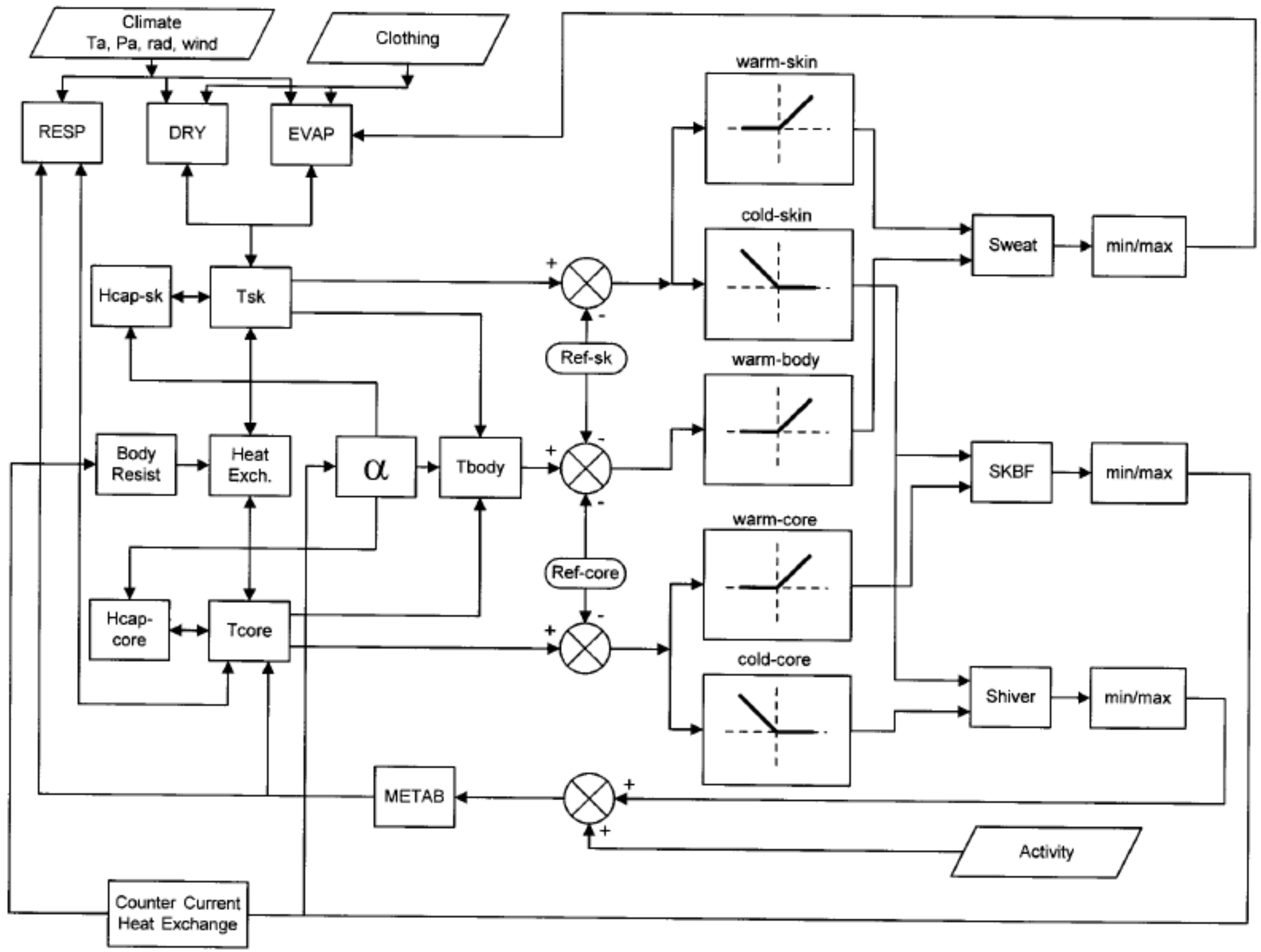


Figure 4. An individualised model of thermoregulation in varying environments and physiological states (Havenith, 2001).

It would seem plausible to predict that those with higher levels of body fat would deal with cold conditions better than those with less body fat (lean) because of the insulative properties of fat. Such a response was observed during a study into the required time for optimal cryotherapy, as those with more body fat required longer cooling periods; 25 minutes: lean; 40 minutes: overweight, to reduce endogenous temperatures to the required levels (Otte et al., 2002). But, a study investigating the thermoregulatory responses of lean and overweight subjects during hot and cold exposure reported some surprising results.

The study by Ooijen et al. (2006) exposed overweight and lean subjects to cool conditions (15 ^{o}C) with a re-warming phase. It was reported that there was no differences in endogenous temperatures between lean and overweight subjects, although thermoregulatory responses did differ. Lean subjects had significantly higher levels of heat production compared to overweight subjects (17.2% vs. 6.4%). This indicates that overweight subjects have better insulative potential through subcutaneous fat although this can be offset in lean subjects by more efficient heat production (Ooijen et al., 2012). This indicates that there is a positive linear relationship between body size and temperature preservation rather than temperature production. Although the reduction in trunk temperature in overweight participants indicates that if they were exposed to extremely cold conditions they may not have the heat producing capacity of lean subjects due to a blunted cold thermogenic response (Ooijen et al., 2012).

These findings are reinforced when the work of Matsumoto et al. (1999) are considered; in which subjects with greater body masses were shown to have suppressed sympathetic nervous system response when compared to lean subjects. As the sympathetic nervous system is responsible for numerous thermoregulatory responses it seems plausible to suggest that larger subjects do not possess as efficient thermoregulatory responses as lean subjects (Matsumoto et al., 1999). Which in turn may mean that larger subjects may have an inferior thermoregulatory response to hot and cold conditions, even though larger subjects tend to display better insulative potential through subcutaneous fat.

Inferior thermoregulatory responses in larger subjects were also observed in a study investigating the accilimation responses of overweight and lean children (Dougherty et al., 2009). The overweight subjects did not experience as larger reduction in core temperature as the lean subjects and also had higher baseline core temperatures. Larger subjects also displayed a slower increase in sweating rate response to acclimation (Dougherty et al., 2009).

This trend is further reinforced by Gardner et al. (1996); where lean (BMI <22) and larger (BMI >22) subjects were exposed to a marine corp training course in hot conditions. Gardner et al reported that larger subjects took longer to complete a 1.5 mile time trial and were at a significantly higher risk of developing heat illness. Only 18% of recruits met the criteria of a BMI exceeding 22 but these recruits made up 47% of those who suffered from heat illness (Gardner et al., 1996).

2.6.3. Cognitive Performance in Varying Environmental Conditions

2.6.3.1. Cold Exposure and Cognitive Performance

Research into the effects of cold exposure on cognitive function is sparse and somewhat contradictory. Many activities, occupational pursuits, and sports are carried out in cold conditions; including GLO in UEFA competitions (Moscow; Russia -5 ^{o}C) (MetOffice, 2012b). Although findings from previous studies (Mäkinen et al., 2006) fail to provide complete clarity as to the effects of cold exposure on cognitive performance trends are apparent. There appears to be a strong link between the reduction in core body temperature and cognitive performance, although small reductions (~0.5 ^{o}C) tend not to have a significant effect (Marrao et al., 2005). Also a trend in cognitive decrement with regards to the difficulty of the task: complex versus simple exists, with complex tasks suffering a much more noticeable change (Muller et al., 2012). Two key theories have been proposed as to why cognitive performance is altered during cold exposure; distraction (Teichner, 1958) and the arousal hypothesis (Enander, 1987). Although both theories attempt to propose the reduction in cognitive performance in cold conditions they lack strong physiological underpinning.

Areas of reoccurring variance in research focussed upon the effect of cold exposure on cognitive performance include the temperature at which subjects are exposed to, the cognitive tests performed, and how the two interact to provide cognitive decrements or improvements. Enander (1987) exposed subjects to two conditions: temperate 21 ^{o}C and cold 5.5 ^{o}C in two separate experiments with experiment one utilising simple cognitive tasks as a performance measure and experiment two using complex cognitive tasks. Simple tasks included a colour recognition vigilance task and simple reaction time; complex cognitive tasks included digit recognition (odd or even), a modified colour recognition vigilance task (more stimuli to respond to) and digit addition. Findings of experiment one reported that cold exposure had no significant effect on cognitive performance when compared to temperate. A lack of change in cognitive performance was in line with a lack of change in core temperature across conditions. If core temperature is not significantly affected by ambient conditions it is expected that the conditions are not stressful enough to affect cognitive performance (O'Brien et al., 2007b). Cognitive performance was affected by cold exposure when complex task were carried out; increases in negative responses during digit classification and an increase in false alarms during the vigilance task were observed. Although increases in negative responses were observed similar to experiment one core temperature was not significantly altered. The study by (Enander, 1987) provides evidence for the task dependency of cognitive decrement during cold exposure. Although caution must be taken when interpreting the results as some confounding factors are present. Experiment one used solely male subjects where as experiment two used solely female subjects, thus it may be differences in sex causing the difference in cognitive performance not the complexity of the tasks at hand. This is most noticeable in the cooling rates between experiments in which females' endogenous temperatures reduced quicker than males which will have affected performance. Moreover the extent of exposure to environmental conditions was not reported; the effects of varying the length of cold exposures are relatively unknown but one would predict that longer exposure to cold conditions would have a larger detrimental effect than shorter bouts of exposure.

Similar findings were reported by (Muller et al., 2012) in which subjects were exposed to 10 ^{o}C cold air for 2 hours with a re-warming phase to follow. Subjects completed a series of complex cognitive tasks at baseline during cold exposure and during the re-warming phase, tasks included; digit span which measures attention and working memory, reaction time and two tasks employed to measure executive function performance; verbal interference task and an executive maze task. No simple tasks were included. Muller et al. (2012) observed significant decrements in working memory, choice reaction time and executive functioning during cold exposure. All decrements persisted into the re-warming phase even though all physiological measures were back to the levels recorded at baseline which is the first finding of its kind.

A study by Makinen et al. (2006) used similar environmental conditions to that of Muller et al. (2012): 10 ^{o}C for 2 hours, but with less conclusive findings. Subjects were exposed to cold conditions for 10 consecutive days with a view to observing an acclimation effect of cold exposure on cognitive performance. Cognitive tests were carried out on all 10 days, although only results for days 1, 5 and 10 were reported. Cognitive performance was measured using the 'Automated Neuropsychological Assessment Metric for Isolated and Confined Environments' (ANAM-ICE) which is a battery of tests including; reasoning, match to sample, reaction time, and Sternberg Memory Search which measures information processing. Over the

10 days exposure percentage of correct responses increased significantly. Task efficiency improved across the 10 days during cold exposure for match to sample, reasoning and others. Response time significantly reduced across the 10 days during cold exposure too. Although, Makinen et al. (2006) reports that when individual test scores are examined cognitive performance was worse in cold conditions when compared to control conditions. Following regression analysis it was reported that cold exposure was an independent factor in causing detriment to cognitive performance. Unfortunately data is only reported for days 1, 5 and 10 which indicate that cognitive performance did not vary noticeably from day to day.

A study which encompasses the issue of temperature in cognitive performance during cold exposure is that of Marroa et al. (2005). Subjects were divided into 5 groups who all completed the same 9 day Canadian Survival, Evasion, Resistance and Escape (SERE) course during winter months. All groups undertook the same tasks over the 9 days and all carried out the same cognitive measures; planning, reasoning and vigilance on all days except day 6. Morroa et al. (2005) reported no differences in cognitive performance between groups and a mixture of small improvements and decrements across days in some groups, which were non-significant. Such findings seem reasonable as all subjects have received the same training with the only apparent difference being the groups in which they were assigned. On inspection it appears that the 5 groups carried out the course at different periods of the winter season as mean ambient temperature varied from 4.4 ^{o}C to -24.4 ^{o}C. This indicates that there is either a ceiling effect of cold induced decrement to cognitive performance, or, that the behavioural responses of the groups differed i.e. the group exposed to -24.4 ^{o}C carried out activities and actions to offset the additional cold. Because subject behaviour was not controlled the findings of this study must be read with caution.

Early explanations of cold induced decrement in cognitive performance suggested that distraction (Teichner, 1958) was the cause with later research claiming arousal caused alterations in cognitive performance during cold exposure (Enander, 1987). Teichner's (1958) theory of cold induced distraction explains that cold exposure (discomfort and the perceived threat of cold) provide a competing stimuli to that of the cognitive test at hand. This is most noticeable in tests of reaction time in which the cold stimulus interrupts the fore-period of reaction which will increase the latency of reaction time, which was observed in Teichner's study (1958). Teichner goes onto explain that acclimated subjects should not suffer the anxiety and intense stress that occurs with infrequent acute cold exposure and thus should not suffer distractive behaviours. This was observed in Makinen et al's (2006) 10 day cold exposure study in which subjects improved accuracy and reduced reaction time over the 10 day period. Conversely, Morroa et al. (2005) found no improvement over a 9 day survival course in the cold; equally there were no decrements across time either.

Enander (1987) explains that cold induced changes in cognitive performance may be a result of fluctuating arousal. The theory of arousal explains that a stressor can improve performance as well as cause decrement depending on the level of stress. It is suggested that cold exposure that reduces core temperature by ~0.5 °C may serve as enough of a stressor to challenge subjects into giving greater attention to cognitive tasks and thus performing better (Mäkinen et al., 2006). Such a hypothesis may be plausible in studies where temperatures do not drop below 10 °C but it is expected that very cold temperatures prove to greater stressor for subjects and performance will deteriorate (Mäkinen et al., 2006).

Interestingly, Muller et al. (2006) explains that the findings of their study cannot be attributed to either distraction or the arousal hypothesis; because subjects performed as badly on all cognitive tests during cold exposure as they did during the re-warming phase. During the re-warming phase all physiological measures had returned to baseline and subjects were exposed to 25 °C air for a prolonged period. Muller et al. (2012) proposed numerous possible physiological causes for cognitive decrement during cold exposure, although none of these were measured during the study. It is suggested that because executive functions which take place in the prefrontal cortex suffer considerable decrement during cold exposure brain temperature may be affected. As brain temperatures are regulated and effected separately to that of the core and periphery (Harris et al., 2008) cognitive performance could be effected even after core and peripheral temperatures return to baseline. An alternative hypothesis suggested by Muller et al. (2012) explains that acute exposure to cold conditions alters the vasculature of areas such as cutaneous circulation and the brachial artery but it is unknown how changes in vasculature within the brain may affect cognitive performance.

Finally, a hypothesis that has been provided by more recent authors (Mäkinen et al., 2006, Muller et al., 2012, O'Brien et al., 2007b) is a cold induced alteration in circulating hormones and catecholamines. Central catecholamines such as dopamine and norepinephrine are required for cognitive functioning, especially those functions which take place within the prefrontal cortex. Thermoregulatory responses to cold exposure also require catecholamines to function, and during their activation it may cause dysfunction in the delivery of catecholamines to important areas of the brain; affecting cognitive performance.

The variance in temperatures at which subjects are exposed to and the variance in cognitive tests they carried out during exposure makes it difficult to draw a conclusion of the effect of cold exposure on cognitive performance. Although it appears that exposure to very cold cold conditions (<5 ºC) effects the performance of executive functions where as simple cognitive functions tend to be less affected.

2.6.3.2. Cognitive Performance and Heat Exposure

Similar to cold exposure, the effects of heat exposure on cognitive performance are not well understood, especially at rest (Hancock and Vasmatzidis, 2003). The extent to which heat has an effect on cognitive performance has previously been attributed to the difficulty of the task, that is; simple tasks such as reaction time are unaffected, where as more complex tasks such as vigilance, tracking and multiple tasks are more visibly affected by heat (Hancock, 1982, Grether, 1973).

A study conducted by Racinais et al. (2008) investigating the effect of passive heating with and without head cooling reinforces the theory of task difficulty dependence. Subjects were exposed to 45 minutes of heating (50 °C, 50% RH) with and without head cooling. Cognitive performance was measured using 5 measures; simple cognitive functions: match to sample, choice reaction time and information processing (recognition of number sequences); and complex cognitive functions: spatial span (recognition of shapes) and pattern recognition. The three simple tasks were measures of attention and none of those tests were significantly affected by heat exposure when compared to control (22 °C). The complex tasks which utilised the prefrontal cortex, measures of complex memory were significantly worse in the hot condition compared to heat exposure with head cooling and control. Similar to previous postulations simple cognitive processes tend to be unaffected during heat exposure, but those complex tasks that require the prefrontal cortex suffer considerable decrement (Racinais et al., 2008).

Simmons et al. (2008) employed a similar protocol using variations of heat exposure and investigating its effects on cognition. Utilising a head cooling condition during heat exposure compared to a control condition (passive heating without head cooling). The cognitive tests used included: simple reaction time; vigilance; choice reaction time and information processing. Facets of all cognitive tasks were compiled to calculate power of attention, which was unchanged between the cooling condition and control. It was observed that small increases in core temperature improved power of attention although this was non-significant. Simmons et al. (2008) explains that passive heating tends to decrease the reaction time of cognitive tasks but also reduces the accuracy during the tasks. It would appear that during passive heating at rest cognitive performance may be more strongly associated with increases in skin temperature and reductions in thermal comfort rather than increases in core temperature (Simmons et al., 2008b). This would lend strength to the theory of distraction.

2.6.3.3. Theory of Arousal – Maximal Adaptability Model

The theory of arousal can be applied to fluctuations in cognitive performance during both exposures to cold and hot conditions. The theory of arousal is based on the inverted U theory which explains that too little or too much arousal (from a stressor) will cause degradations in performance. Whereas moderate environmental stress may alter physiology enough to invoke an improvement in cognitive performance. The inverted U theory is elegant in design, but somewhat one dimensional and dated being cited as early as the mid 20th century (Martens and Landers, 1970). The need for a more complex, explanatory model is required to truly understand the interaction of environmental stress, arousal and cognitive performance.

The Maximal Adaptability Model (Hancock and Warm, 2003) assumes that the decrement in cognitive performance observed during heat exposure is a result of a heat induced degradation in attentional resources (Hancock and Vasmatzidis, 2003) see figure 5.

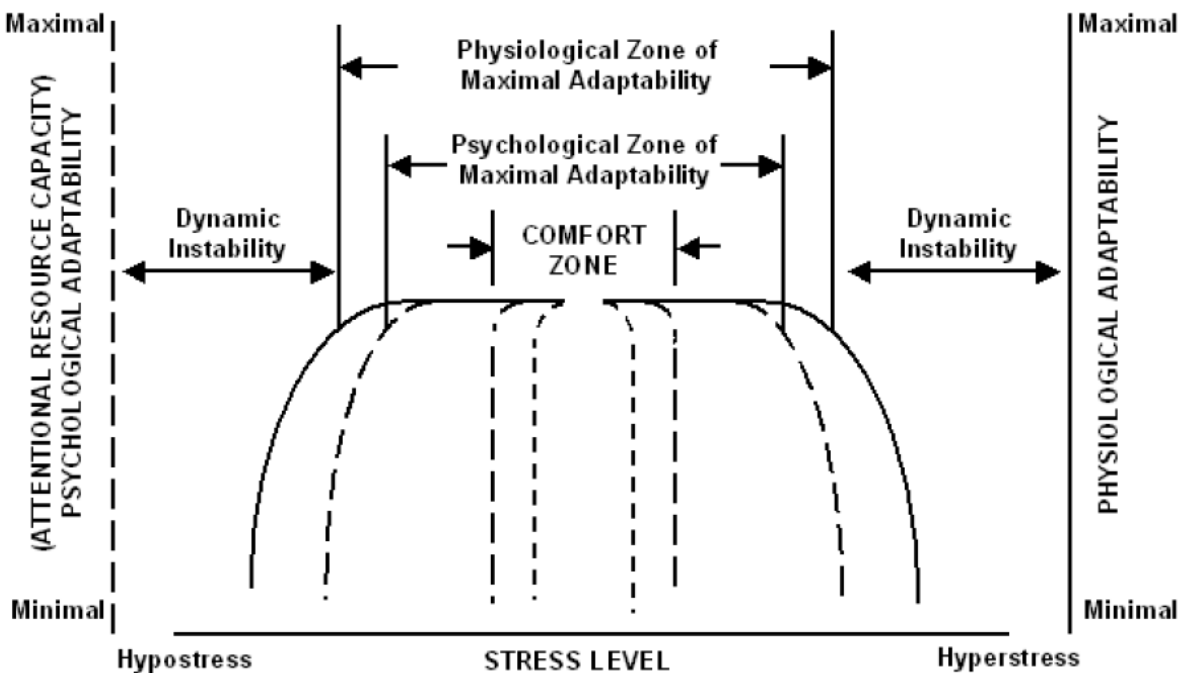


Figure 5. The maximal adaptability model; a multi-zonal description of cognitive performance during varying levels of arousal.

The Maximal Adaptability Model explains that when a subject is within the 'comfort zone' cognitive tasks should be carried out optimally. Within the comfort zone environmental stress will be not be stressful enough to incur any substantial changes to psychological adaptability or physiological adaptability. Psychological adaptability is one's ability to use psychological resources effectively, for example in moderate stress subjects are able to focus their attention at the task at hand, and not focus upon the surrounding environment. Physiological adaptability is the physiological response to environment stress, i.e. thermoregulatory systems: vasoconstriction/vasodilation etc... As environmental stress increases cognitive performance begins to deteriorate as psychological resources begin to deplete, noticeable reductions in cognitive performance begin when subjects leave the 'psychological zone of maximal adaptability'. As environmental stress increases physiological adaptability also begins to reduce, for example; as ambient temperatures continue to increase the thermoregulatory system becomes overwhelmed and core temperature will continue to rise. As subjects begin to move away from the level of optimal stress, 'the comfort zone' psychological and physiological strains which are intertwined become too great and at first begin to cause decrement to performance, and should such environmental stress be sustained cause decrements to health.

GLO are exposed to a variety of environmental conditions when officiating in UEFA Cup Competitions; cold, temperate and hot ambient temperatures. These varying conditions will affect the performance of GLO differently as outlined in the previous sections. Scientific investigation into the effect of varying environmental conditions is required to prove or disprove the hypothecation that cold exposure will significantly reduce GLO performance when compared to temperate and hot conditions. Findings of such a study are of critical importance to UEFA and the wider soccer community because if GLO cannot perform optimally in certain environmental conditions then methods to ameliorate such effects should be considered, or GLO may need to be replaced by goal line technology.

3.0.Research Question and Hypotheses

3.1.Research Question

1. To investigate the effects of extreme environmental conditions on the decision making ability of participants carrying goal line official-like movements.

3.2.Hypotheses:

1. Exposure to cold conditions will significantly reduce the decision making ability of participants carrying out goal line official-like movements when compared to temperate and hot conditions.
2. Exposure to hot conditions will significantly improve the decision making performance of participants carrying out goal line official-like movements when compared to cold conditions but not temperate conditions.

4.0.Methodology

4.1.Health and Safety

All procedures were approved by the University of Bedfordshire ethics committee. Two experimenters were present during all testing sessions, with first aiders on hand if required. All reusable equipment such as, heart rate monitors and skin thermistors were cleaned before every use. All non-reusable equipment such as rectal thermistors were incinerated after use.

Criteria for the termination of testing:

- If the subject requested that testing be stopped
- If the experimenter felt it necessary: if the subject was displaying symptoms of heat/cold illness, for example, significant changes to core temperature, lack of lucidity, heat exhaustion, severe discomfort.
- Significant changes in core temperature include: a drop of >1.5 ºC from resting baseline value. Or, an increase in core temperature of more than 2.0 ºC or greater than 39.7 ºC which ever was observed first. If either of these criteria are met testing will be immediately terminated according to the guidelines set out by the University of Bedfordshire ethics committee.

4.2.Subjects

13 subjects included both undergraduate and post graduate male students (age: SD: age= 19.6 ± 6, height= 171 ± 11 cm, body mass= 64.4 ± 13 kgs) from the University of Bedfordshire, all of which regularly took part in training and competition of game sports.

4.3.Diet & Lifestyle Standardisation

Pre-experimental diet and life style requirements were explained in full to all participants before they agreed to take part in the study. All subjects were required to adhere to these requirements in order to maintain the integrity of the study and its findings. Table 2. describes the diet and lifestyle expectations prior to testing.

Table 1. Lifestyle requirements subjects must adhere to prior to and during testing.

Control Measures	Duration	Reasons
No intense exercise (e.g. no more intense than a light jog)	24hours prior to testing	May induce premature fatigue
No Alcohol	24hours prior to testing	May effect cognitive performance
No caffeine	12hours prior to testing	May effect cognitive performance
No acclimation to extreme cold or hot environmental conditions	1 month prior to testing	May effect cognitive and physiological response to extreme hot/cold

Subjects were questioned on their adherence to the agreed diet and lifestyle standardisation prior to each session of testing. If subjects have not adhered to the lifestyle standardisation experimental testing was postponed until the standardisation criteria was successfully completed.

4.4. Experimental Design

Participants made a preliminary visit to the Sport and Exercise Science Laboratories at the University of Bedfordshire for a tour of the facilities that were used throughout testing. The following 2 visits were familiarisation sessions. Participants then made a further 5-6 visits during which the experimental conditions were completed. The 5-6 visits allocated for experimental testing encompass all environmental conditions employed, these include; cold; 5ºC, 40% relative humidity; temperate; 18 ºC, 40% relative humidity; hot; 30 ºC, 40% relative humidity. These various conditions were employed to mimic the differing environmental conditions experienced throughout European cup competitions (Europa League, UEFA Champions League).

The protocol employed during both the familiarisation sessions and experimental conditions was designed to mimic the match day performance of a goal line official. It included a 45 minute period of small lateral movements, followed by a 15 minute half time break, finally another 45 minute period of small lateral movement was completed. This was interspersed with 4 computer based cognitive tests designed to measure vigilance, visual tracking and attentional ability.

The relevant temperatures and humidity were attained using the University of Bedfordshire's environmental chamber. The chamber was examined prior to experimental testing for validity and reliability.

4.5.Familiarisation to Experimental Protocol

As some of the subjects were unfamiliar with the process of scientific testing and the equipment being used familiarisation was split into two sessions to reduce the strain on subjects.

4.5.1. Visit 1: The Protocol

During visit 1 anthropometric measurements were taken for each subject. They included; height, measured using a stadiometer (Harpenden stadiometer, Holtain Ltd, Crosswell, UK) measured to the closest 0.1cm, subjects were required to stand upright and inhale maximally, the stadiometer was then lowered to the top of the subjects head, the measurement was then recorded. Body mass was attained using electronic scales (Tanita BC-418MA, Tanita UK Ltd, Middlesex, UK) measured to the closest 0.1kg. Body composition was assessed using air displacement plethysmography (BodPod 2000A, Cranlea, Birmingham, UK), body fat was measured to the nearest 1%.

During visit 1 subjects completed the 90 minute protocol, including all 4 cognitive tests, as described in figure 1. No physiological data was recorded during visit 1. The 90 minute protocol was completed in temperate conditions (18 ^{o}C, 40% RH).

4.5.2. Visit 2: Physiological Measurements

Similar to visit 1 subjects completed the 90 minute protocol, including all 4 cognitive tests in comfortable conditions (~18 ^{o}C, 40% RH). Physiological data was recorded during this visit including: core temperature; measured using a rectal thermistor, a small, flexible, plastic thermometer inserted 10 centimetres past the rectal sphincter(Henleys, 400H and 4491H, Henleys, Herts, UK). Skin temperature thermistors were applied located at four sites; the posterior belly of the gastrocnemius, the anterior belly of the vastus intermedius, the anterior belly of the pectoralis major, and the posterior belly of the triceps brachii (Ramanthan, 1964)(Grant, EUS-U-VS5-0, Wessex Power, Dorset, UK). Heart rate was measured using a heart rate monitor (Polar Electro Oy, Professorintie 5, FIN-90440, Finland). Rating of perceived exertion; this subjective measure indicates how hard a subject feels they are working. The Borg scale a numerical scale starting at 6 (very light workload) increasing to 20 (maximal workload) was used to measure ratings of perceived exertion (Borg, 1970). Thermal sensation was also measured, this is also a subjective measure used to indicate how hot or cold a subject is feeling. An 8 point scale was used to measured thermal sensation which starts at 4 (neutral/comfortable) and increases to 8 (unbearably hot) or reduces to 0 (unbearably cold) as described by Toner et al, 1986).

4.6. Experimental Procedures

4.6.1. The 90 minute Protocol

A specific 90 minute protocol was devised to replicate the movements and cognitive demands placed upon a goal line official (GLO) during a football match. A protocol timeline is described in Figure 6.

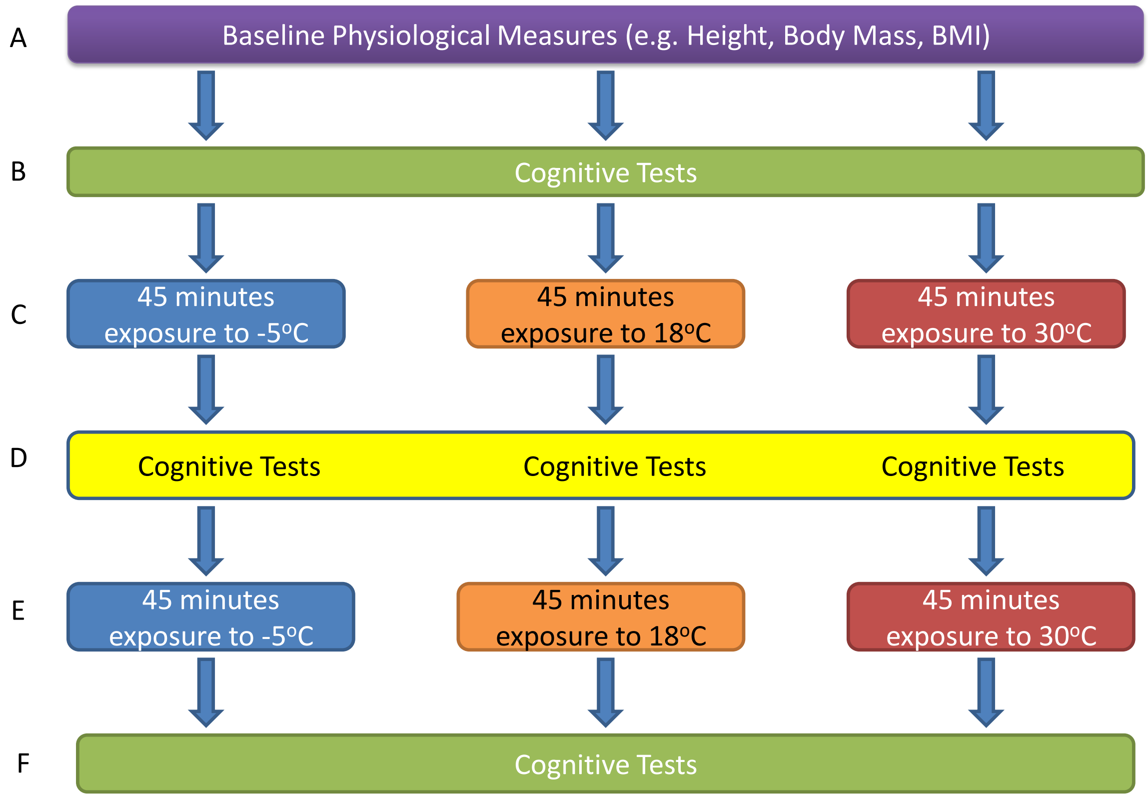


Figure 6: Chronological layout of the 90 minute experimental procedure.

During the two 45 minute exposure phases (Stage C & E) subjects performed small lateral movements; side-stepping inside a small box (2 X 1 metres) marked out on the floor of the environmental camber. During lateral movement subjects kept their arms at their side and head facing forward. Small lateral movements were selected as the method of exercise as it mimics the minimal movement produced by GLO during a football match. Subjects were given some freedom as to how much they moved as long as they were not static for the entire phase, and stayed within the box marked out on the floor. The box was marked out on the floor to offer some standardisation for the lateral movements. Subjects watched a football match on a large television through a window in the environmental chamber during both 45 minute exposures. The same football match was used for all experimental trials.

Cognitive tests were performed at 4 stages throughout the 90 minute protocol. The first was completed prior to any exposure to the various environmental conditions (Fig. 3, Stage B). The second was completed immediately after the first 45 minutes of exposure (Stage D). The third cognitive stage was carried out on the completion of the 15 minute half time break (Stage D), immediately before the second stage of exposure. The final cognitive test was completed immediately on completion of the second exposure phase (Stage F). All cognitive tests were completed in the environmental chamber.

4.7.Equipment and Apparatus

4.7.1. Physiological Measures

Rectal temperature was the chosen method used for the measurement of core temperature. General medical tape was applied to a rectal thermistor (Henleys, 400H and 4491H, Henleys, Herts, UK) to form a bunge was constructed to indicate the 10cm insertion depth. Rectal temperature was recorded at 5 minute intervals. Similarly, skin temperature (Grant, EUS-U-VS5-0, Wessex Power, Dorset, UK) was also recorded at 5 minute intervals throughout the protocol. Four skin thermistors were used, placed on the gastrocnemius, rectus intermedius, pectoralis major, and the tricep brachii. Skin thermistors were held in place using general medical tape. Heart rate was recorded using a heart rate monitor (Polar Electro Oy, Professorintie 5, FIN-90440, Finland), and data was recorded at 5 minute intervals. Urine samples were taken pre and post protocol to test for hydration status, urine was analysed using urine refractometer (Atago, l Pocket PAL-OSMO, Japan). A desirable level of hydration reads between 200 - 600 on the urine refractometer. A reading of >600 indicates dehydration, if this occurred subjects were given 500 millilitres of water to drink, and testing was resumed half an hour after fluid ingestion. If a reading of >1000 was observed testing was rescheduled as this suggests subjects were severely dehydrated.

4.7.2. Subjective Measures

Rating of perceived exertion (RPE) (Borg, 1970) and thermal sensation (TSS) (Toner et al, 1986) were taken during the two exposure phases only; recordings were taken at 5 minute intervals. RPE exertion is a scale which indicates the level of physical strain a subject is experiencing. RPE begins at 6 (very, very light) and increases to 20 (very, very hard). TSS indicates the thermal comfort of a subject, starting at 0.0 (unbearably cold) through to 8.0.

The environmental chamber (Custom made, T.I.S.S., Hampshire, UK) was tested for reliability prior to any experimental testing, and was stable to within 1 °C of the desired temperature. Similarly relative humidity was stable to within 1% of the desired humidity.

Figure 7. Interior view of the environmental chamber, showing a subject completing an experimental trial.

4.8.Cognitive Tests

Cognitive performance testing of vigilance, tracking and attentional ability was carried out using the Psyche software package (Hope et al; 1998). The program was run on the same computer for every session of testing. Subjects completed 4 cognitive tests during each visit, as described in figure 6.

4.8.1. Biological Variance

Biological variance testing was completed to ensure that the cognitive tests were valid and reliable. Biological variance was assessed over a period of 7 days in 10 male subjects. This was employed to ascertain the magnitude of natural performance variation across days, such analysis aided in validating the usage of the PSYCHE Software Package (Hope et al., 1998). Any learning effects were ameliorated by day 2 of the 7 with no significant changes in test performance following the second day of the protocol. None of the subjects involved in biological variance testing took part in any experimental trials.

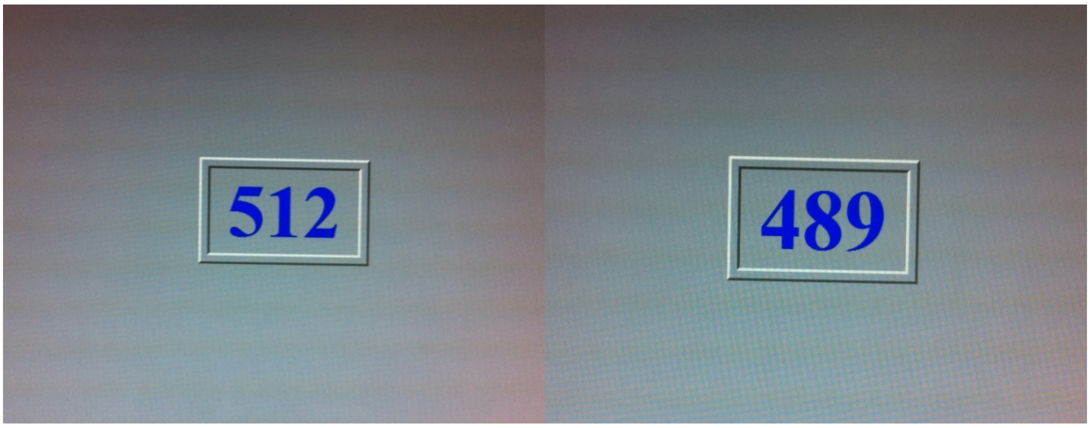


Figure 8. Screen shots of the vigilance task (Psyche).

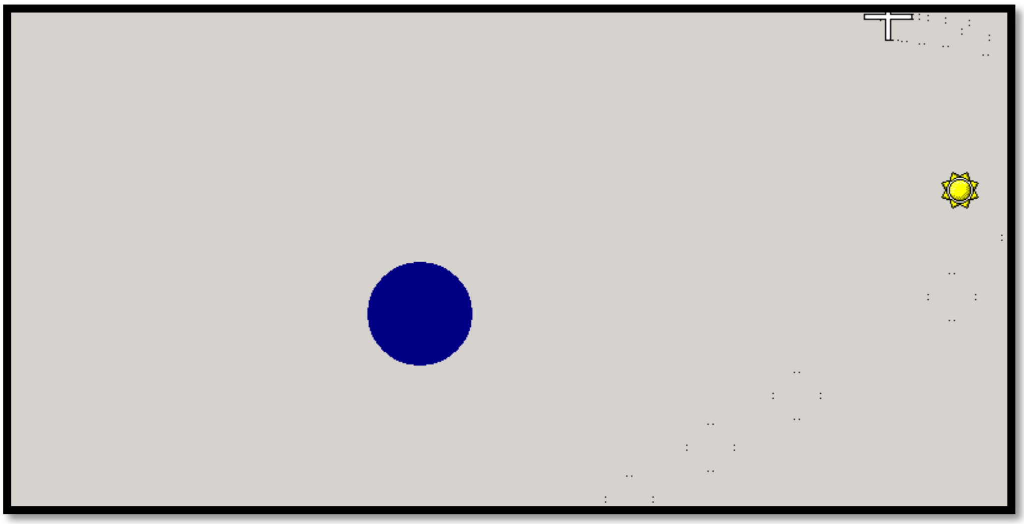


Figure 9. Screen shot the Dual Task test (Psyche)

4.8.2. Vigilance

The numerical vigilance test measured subjects' vigilance performance. The test consists of 3 digit numbers flashing on screen (100 per minute), there is an 8% duplication rate and subjects were required to identify when a 3 digit number is duplicated on screen by pressing the space bar (Hope et al; 1998) (Smith et al., 1992).

This test was originally designed by Smith et al. (1992) in which the test was used to assess the effects of food, drink and daily rhythms on cognitive performance. The test is based on the theory that vigilance is sensitive to changes in arousal, which can be significantly affected by drugs, alcohol or the environment (Millar, 1992).

4.8.3. Dual Task

The dual task measures two facets of cognitive performance simultaneously. Tracking, this required subjects to keep the cursor within a circle, the circle constantly moves around the screen during a 3 minute period. The second aspect of the test measures visual reaction time. While subjects are tracking the circle on screen an icon will randomly appear subjects must hit the space bar on seeing the icon, the register acknowledgment. Measuring these two facets of cognitive function together assesses ones attentional capacity.

Millar (1975) investigated the ability of subjects to focus on two stimuli simultaneously. As it was previously suggested that focusing on two stimuli at the same time would work psychological resources to maximum (Moray, 1974). It is was proposed that if focusing on two stimuli would utilise cognitive resources to maximum then any additional arousal should overload cognitive processing leading to decrements (Moray, 1974). It appears that cognitive usage is task dependant; as concentrating on two simple stimuli such as basic visual/auditory probes leaves spare working capacity. Where was concentrating on more difficult stimuli, for example encoding letters and numbers leaves no spare working capacity. This considered the dual task provided by Hope et al. (1998) employs two difficult stimuli; a constantly moving target and a randomly appearing (both in position and timing) icon.

All cognitive tests were carried out on a laptop computer, tests lasted for 3 minutes; the accuracy of the test duration was validated during pilot work.

4.9.Statistical Analysis

All statistical analyses were completed using IBM SPSS Statistics 18 (SPSS Inc., Chicago, IL). Statistical assumptions were checked using conventional graphic methods and were deemed plausible unless stated otherwise. Central tendency and dispersion are reported as the mean (SD). Data was analysed using a two way repeated measures ANOVA (time x condition). Where significant differences were observed, the Bonferroni post-hoc test was used to identify the conditions and time points at which significant differences occurred. Two-tailed statistical significance was accepted as $P < 0.05$. Stepwise regression analysis was employed to analyse the strength of existing relationships between the dependant and independent variables. Qualitative interpretations of Cohen's D was used to measure size effects; <0.6 = small effect, 0.6 - 1.2= medium effect, >1.2= large effect (Hopkins, 2004). Percentages of change were also calculated from means (SD) for all cognitive tests performed as a qualitative interpretation of performance variance between conditions.

5.0.Results

5.1.Physiological Results

5.1.1. Rectal Temperature

A significant main effect of condition (F=35.507, P=<0.001), time (F=21.807, P=<0.001), and interaction (F=35.507, P=<0.001) on T_{re} was observed. T_{re} during cold (36.9 °C ±0.4) was significantly lower than during temperate (37.07 °C ±0.2) (ES=0.4) (P=<0.001) at 5 minute intervals from 5 minutes to 90 minutes. No difference in T_{re} was observed between cold and temperate at 0 minutes (P=1.000). Similarly, there was no difference in T_{re} at 0 minutes between cold and hot (37.1 °C ±0.3) (P=0.536), but differences were observed at 5 minute intervals from 5 minutes to 90 minutes, resulting in an overall difference between the two conditions (P=0.001) (ES=0.5). A comparison of temperate and hot conditions shows a similar trend with no difference in T_{re} at 0 minutes (P=0.228), followed by a significant differences in T_{re} at all other time points (Temperate < Hot) (P=<0.001).

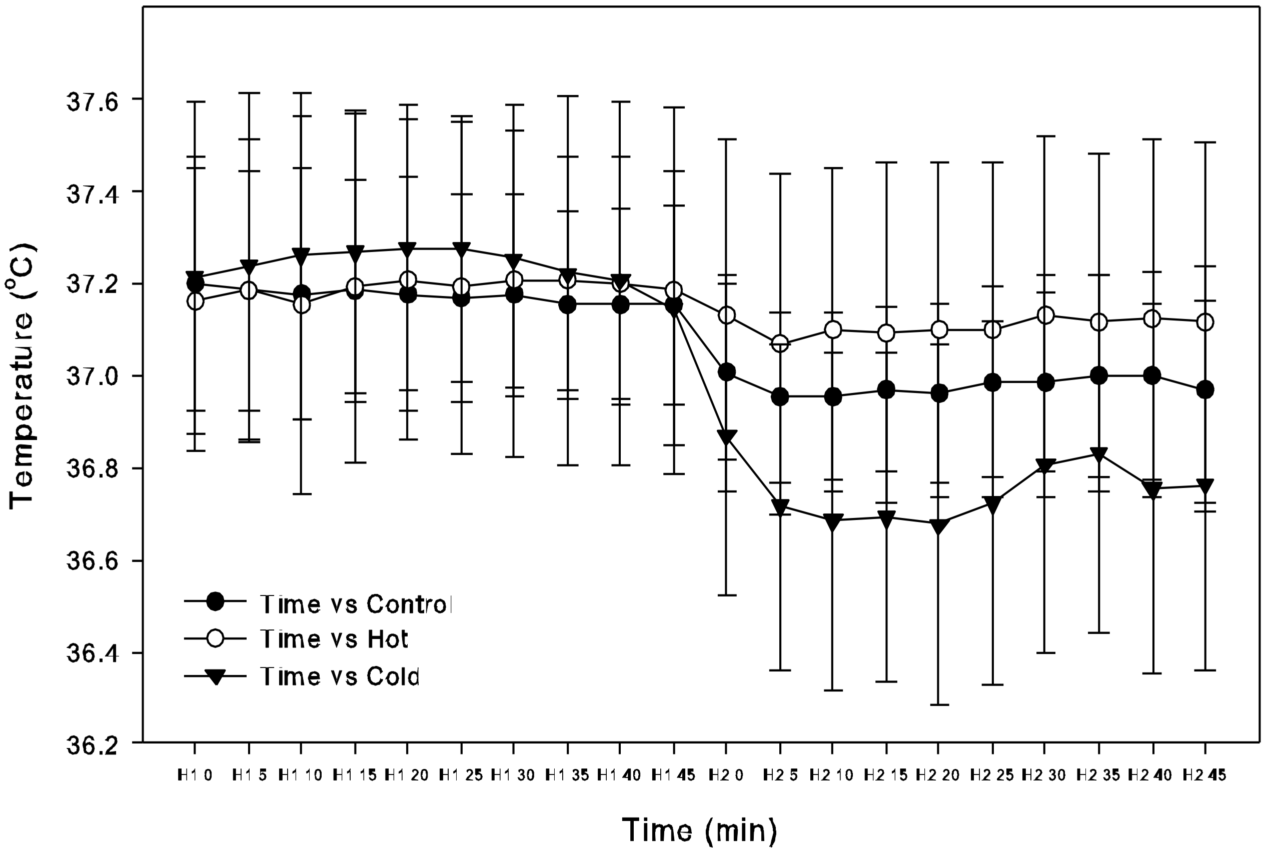


Figure 10. Mean (SD ±) core temperature during 90 exposure to 3 experimental conditions; cold (-5 °C), temperate (18 °C), and hot (30 °C). Significant differences were observed at all time points between all conditions (P<0.05), excluding 0 minutes and immediately after half time.

5.1.2. Skin Temperature

A significant main effect of condition (F=123.415, P=0.023), on T_{sk} was observed. T_{sk} during the cold condition was lower in cold (24.5 °C ±2.6) than temperate (29.4 °C ±1.4) (P=<0.001) (ES=1.8) and hot (33.2 °C ±1.1) (ES=3.3) (P=<0.001). Temperate T_{sk} was also lower than hot (P=<0.001) (ES= 2.7). T_{sk} differed in all conditions at 5 minute intervals from 5 minutes to 90 minutes (P<0.05). The only exceptions to this trend were at 10 minutes, when T_{sk} did not differ between temperate (30.02 °C ±1.2) and hot (32.7 °C ±1.1) (P=1.000), or cold (25.7 °C ±2.1) and hot (P=0.355). Finally, immediately after the restart of the second 45 minutes exposure no differences were observed between cold (27.6 °C ±2.7) and temperate (29.9 °C ±1) (P=0.248).

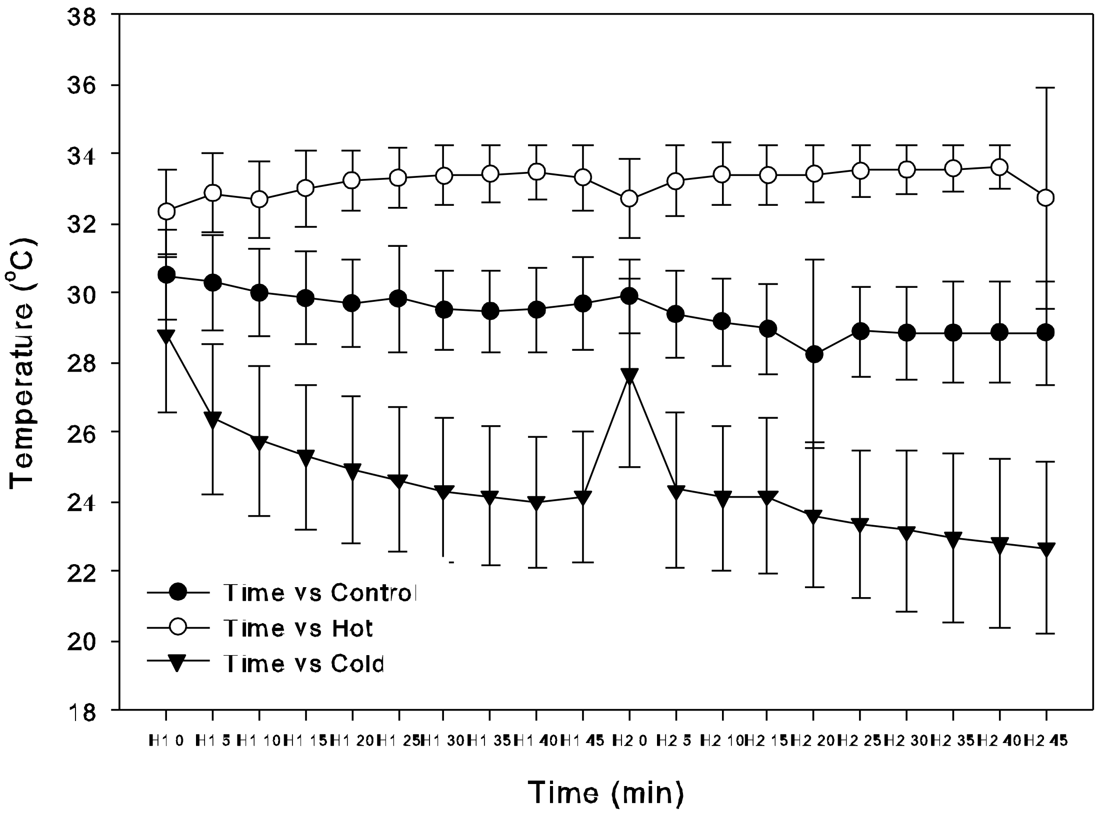


Figure 11. Mean (SD ±) skin temperature during 90 exposure to 3 experimental conditions; cold (-5 °C), temperate (18 °C), and hot (30 °C). Significant differences were observed at all time points between all conditions (P<0.05), excluding 10 minutes and immediately after half time.

5.1.3. Heart Rate

A main effect of condition was observed for heart rate (F=15.909, P=0.005), time (F=7.970, P=<0.001), and interaction (F=3.291, P=0.003). Heart rate was higher in hot (82.1 BPM ±13.9) than temperate (70.8 BPM ±11.7) (P=0.005) (ES=0.9), differences in heart rate were observed from 0 to 35 minutes and from 50 to 90 minutes. Heart rate was also higher in cold (76.2 BPM ±10.8) than temperate (P=0.016) (ES=0.4), differences were observed from 45 to 65 minutes and 75 to 90 minutes. No overall significant difference in heart rate was observed between cold and hot (P=0.119), although differences at 5, 10, 20, 40, and immediately after half time were observed (P<0.05).

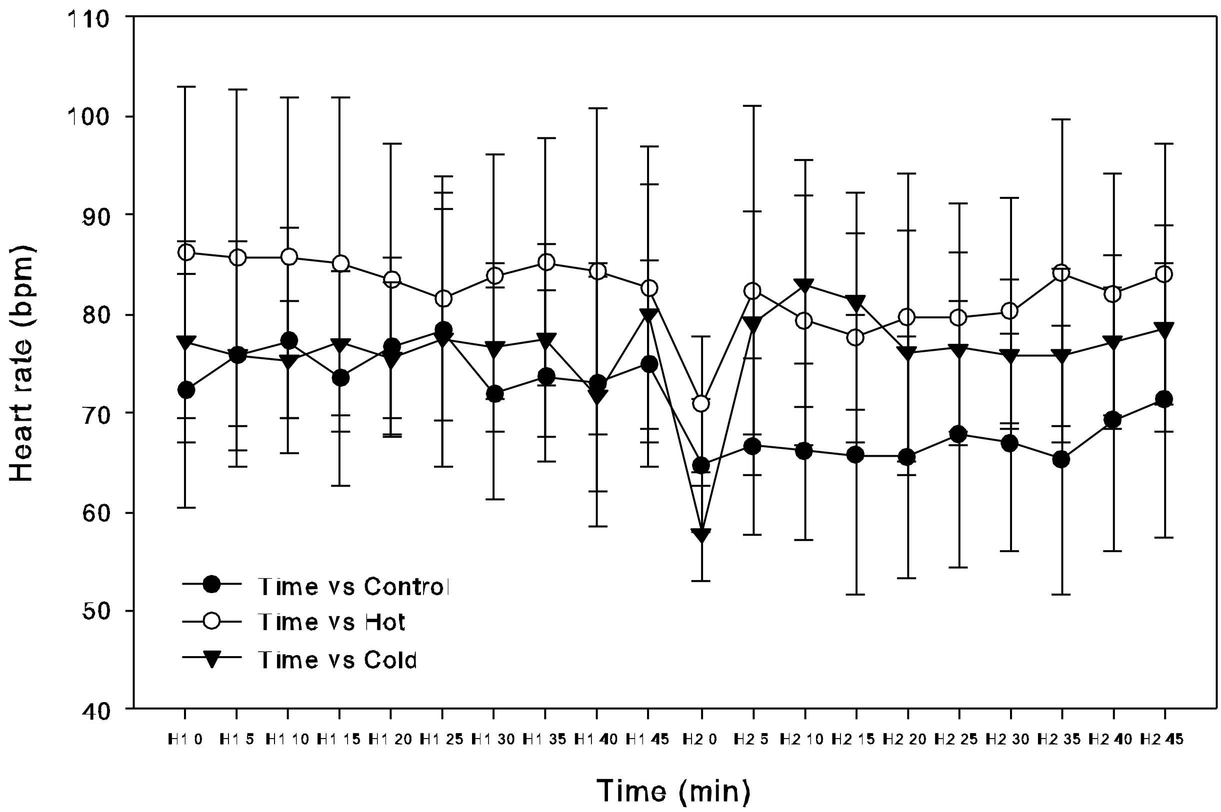


Figure 12. Mean (SD ±) heart rate during 90 exposure to 3 experimental conditions; cold (-5 °C), temperate (18 °C), and hot (30 °C). Significant differences between hot and temperate were observed from 0 to 35 minutes and from 50 to 90 minutes (P<0.05). Significant differences were observed from 45 to 65 minutes and 75 to 90 minutes between cold and temperate (P<0.05). Significant differences between hot and cold were observed at 5, 10, 20, 40, and immediately after half time were observed (P<0.05)

5.1.4. TSS

A main effect of condition (F=409.399, P=<0.001), time (F=21.807, P=<0.001) and interaction (F=35.507, P=<0.001) was observed on thermal sensation ratings. Thermal sensation scores were lower in cold (1.3 ±1) than temperate (3.7 ±0.4) (P=<0.001) (ES=2.4) and hot (5.0 ±0.5) (P=<0.001) (ES=3.7) at 5 minute intervals from 5 minutes to 90 minutes. Similarly, thermal sensation scores were lower in temperate than hot (P=<0.001) (ES=3.25) at 5 minute intervals from 5 minutes to 90 minutes, although there was no difference immediately after the start of the second half (P=0.524).

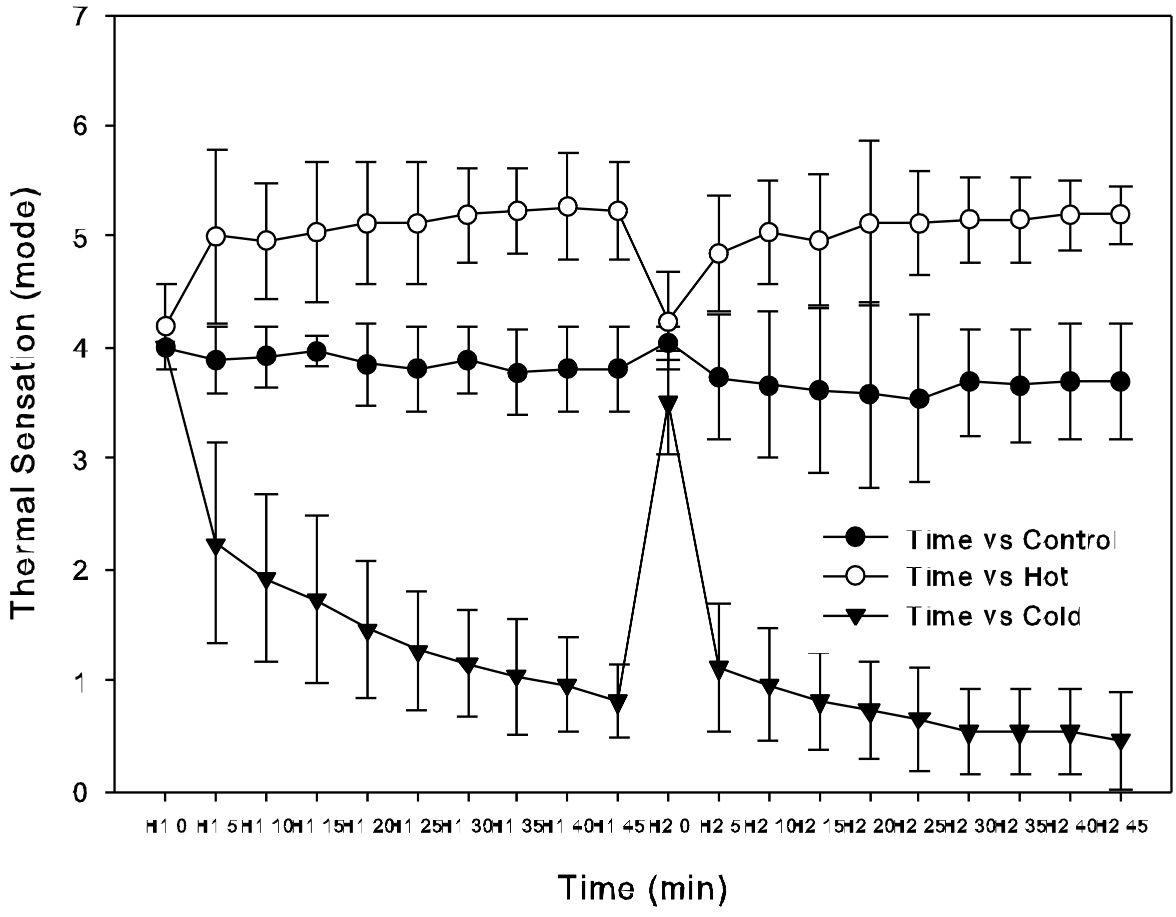
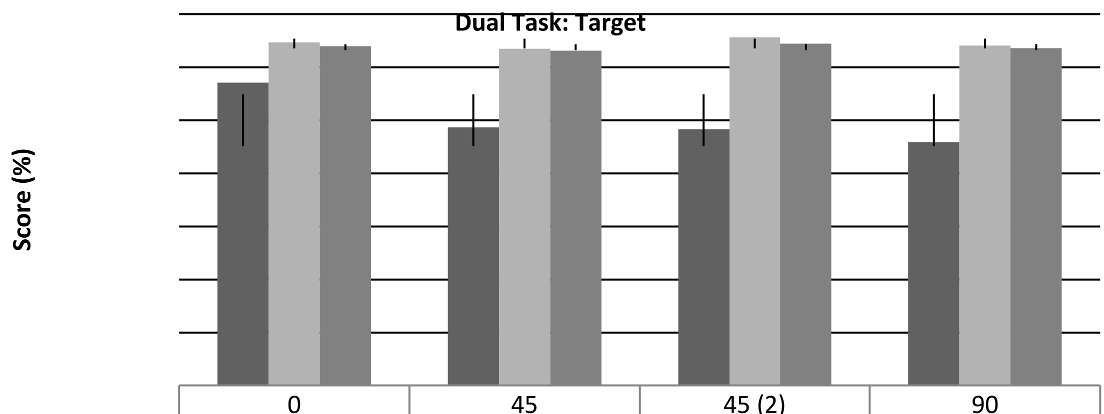


Figure 13. Mean (SD ±) thermal sensation ratings during 90 exposure to 3 experimental conditions; cold (-5 °C), temperate (18 °C), and hot (30 °C). Significant differences were observed at all times points between all conditions (P<0.05), excluding 0 minutes and immediately after half time.

5.2.Cognitive Scores

5.2.1. Dual Task

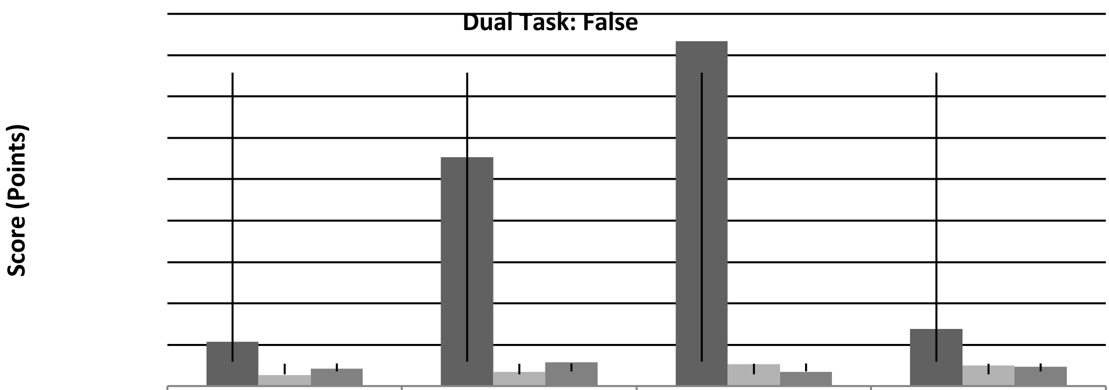
A main effect of condition was observed for Tracking scores (F=10.743, P=<0.001) as well as time (F=9.036, P=0.001) and interaction (F=3.841, P=0.018). Tracking was worse in cold (49.9 ±13.4) than temperate (64.4 ±10.9) (P=0.011) (ES=1) and hot (63.7 ±10.7) (P=0.003) (ES=1). Differences in tracking scores between cold and temperate were observed at 45 minutes (cold: 48.6 ±12.2; temperate: 63.4 ±12.3) (P=0.021), 45 minutes (immediately after half time) (cold: 48.3 ±12.5; temperate: 65.6 ±11) (P=0.002) and 90 minutes (cold: 45.8 ±11.8; temperate: 64 ±10.3) (P=0.001). Differences between cold and hot were observed at the same time points as cold and temperate (P<0.05). Tracking performance in cold was significantly worse than hot at 45 minutes (cold: 48.6 ±12.2; hot: 63 ±11.7) (P=0.016), 45 minutes (immediately after half time) (cold: 45.8 ±11.8; hot: 64.3 ±11) (P=0.002), and 90 minutes (cold: 45.8 ±11.8; hot: 63.6 ±10.5) (P=<0.001).



	0	45	45 (2)	90
Cold	57.07	48.69	48.3	45.84
Temperate	64.69	63.46	65.61	64.07
Hot	64	63.07	64.38	63.61

Figure 14. Mean (SD ±) Dual task tracking scores at all four time points. Tracking performance was worse during cold than temperate during the second, third and forth tests.

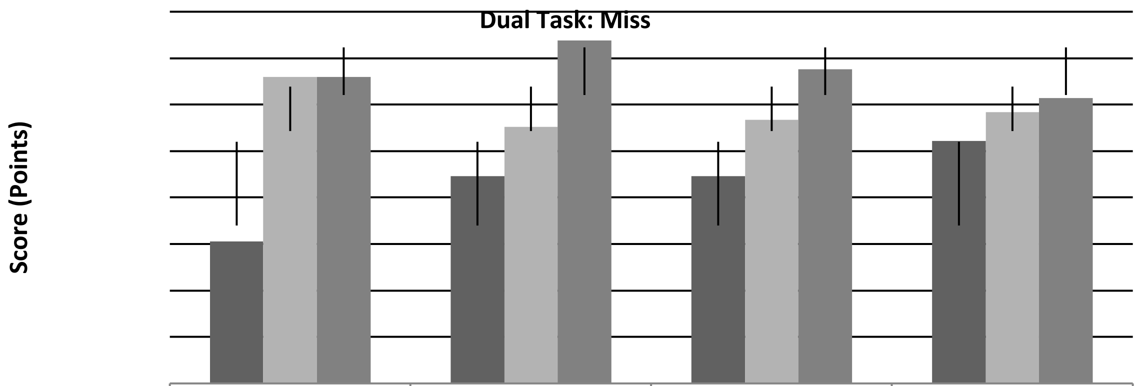
No main effect of condition was observed on FALSE scores for the Dual Task (F=3.079, P=0.100), there was also no main effect of time (F=0.974, P=0.365) or interaction (F=1.002, P=0.359). No significant differences between any of the conditions were observed (cold: 8.1 ±26.5; temperate: 0.8 ±1.2; hot: 0.9 ±1.6) (P>0.05). During the first 45mins exposure to cold conditions FALSE scores increased by 94.6% when compared to temperate and 90% when compared to hot. Similarly during the second 45mins exposure to cold FALSE scores increased by 63% when compared to temperate and 67% when compared to hot.



	0	45	45 (2)	90
Cold	2.15	11.07	16.69	2.76
Temperate	0.53	0.69	1.07	1
Hot	0.84	1.15	0.69	0.92

Figure 15. Mean (SD ±) Dual Task False scores at all 4 time points. False scores were worse in the cold condition at all 4 time points when compared to temperate and hot, although the differences were not significant.

There was no overall effect of condition on MISSED scores during the Dual Task (F=0.347, P=0.710). No overall main effect of time (F=0.098, P=0.905) or interaction (F=0.520, P=0.606) was observed either. No differences between any of the conditions for MISSED scores was observed (cold: 2.1 ±2.1; temperate: 2.9 ±4.2; hot: 3.3 ±4.6) (P=1.000) (ES=Cold Vs. Temp: 0.3; Cold Vs. Hot: 0.5; Temp Vs. Hot: 0). During the first 45mins exposure MISSED scores increased by 18.6% in temperate when compared to cold and 38.9% in hot when compared to cold. Following the second 45mins exposure MISSED scores were 13.4% higher in hot than cold and 10% higher in temperate than cold.

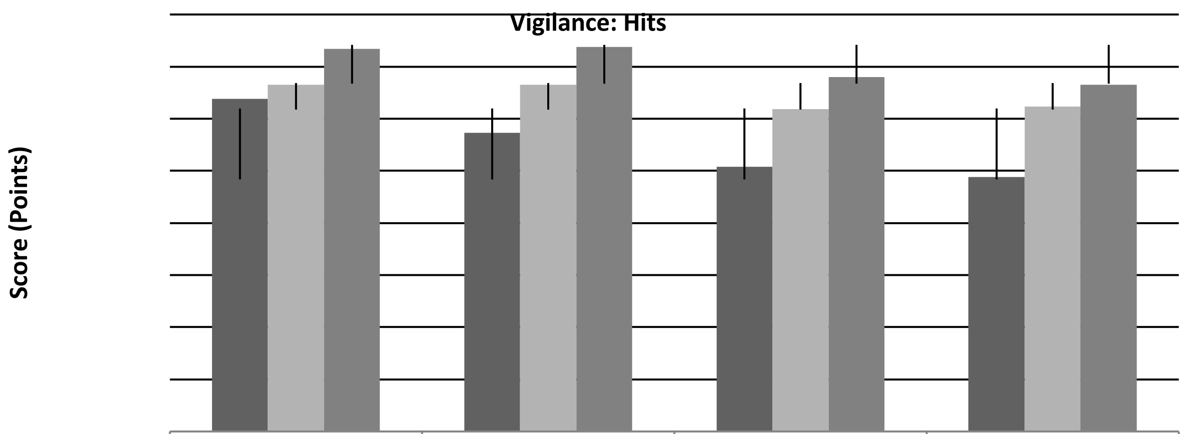


	0	45	45 (2)	90
Cold	1.53	2.23	2.23	2.61
Temperate	3.3	2.76	2.84	2.92
Hot	3.3	3.69	3.38	3.07

Figure 16. Mean (SD ±) Dual Task Missed scores at all time points. Miss scores were not generally higher in any of the conditions which in reinforced by the lack of significant differences (P> 0.05).

5.2.2. Vigilance:

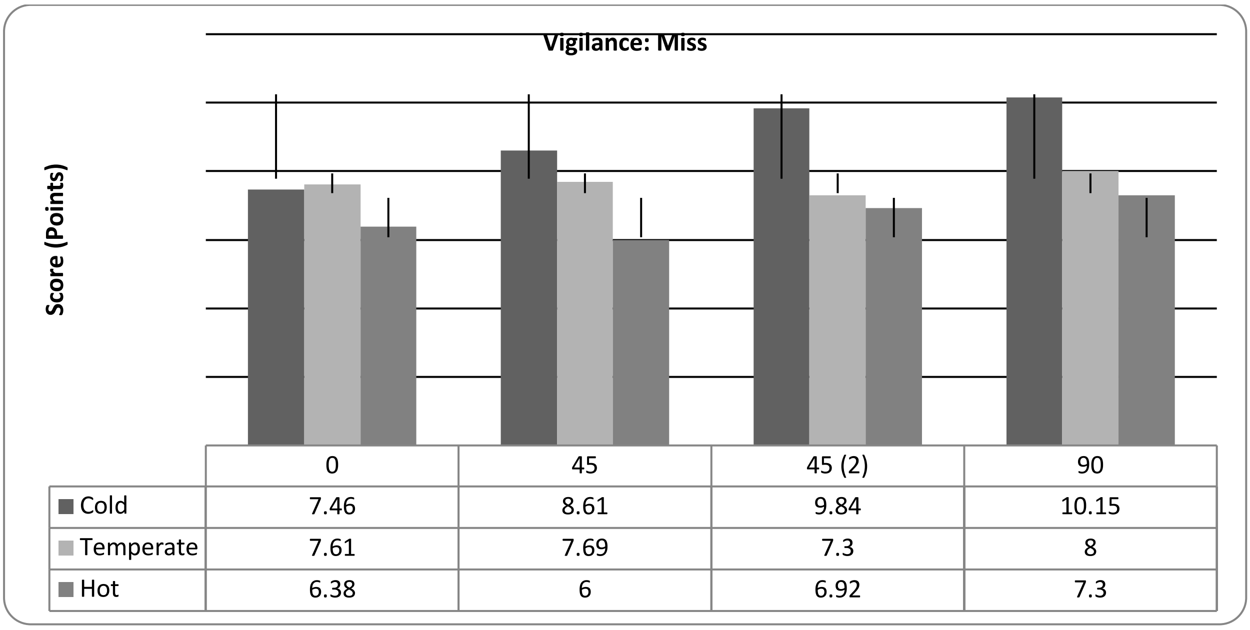
HIT - A main effect of condition was observed on HIT scores during the vigilance task (F= 2.356, P= 0.024), as well as a main effect for time (F=4.762, P=0.010). Although no main effect was observed for interaction (F=0.883, P=0.468). Differences in HIT scores were observed between cold (11 ±5.3) and hot (14 ±3.5) (P=0.025) (ES=0.5). Significant differences in HIT scores were observed after 45 minutes exposure (P=0.024) and immediately after half time (P=0.039). No other differences were observed between conditions, cold (11 ±5.3) and temperate (12.8 ±2.8) (P=0.503) (ES=0.3); temperate and hot (P=0.538) (ES=0.4). Hit scores were 22.5% higher in hot than cold after the first 45mins exposure. Following the second 45mins exposure hit scores 27.1% higher in hot than cold and 21.8% higher in temperate than cold.



	0	45	45 (2)	90
Cold	12.76	11.46	10.15	9.76
Temperate	13.3	13.3	12.38	12.46
Hot	14.69	14.76	13.61	13.3

Figure 17. Mean (SD ±) Vigilance Hit scores at all time points. Hit scores were higher in the hot condition when compared to cold (P<0.05), no other significant differences were observed.

No main effect of condition was observed for MISSED scores either (F=2.966, P=0.108). There was no a main effect of time (F=2.595, P=0.070) or interaction (F=1.932, P=0.138). Even so MISSED scores were significantly higher in cold (9 ±4) than hot (6.2 ±3.3) (P=0.037) (ES= 0.8), after the second 45 minutes exposure but no difference between any of the other conditions cold vs. temperate (7.3 ±3.7) (P=0.390) (ES=0.4) or temperate vs. hot (P=0.1000) (ES=0.3). Following the first 45mins exposure MISSED scores were 30.3% higher in cold than hot and 20.8% higher in temperate than hot. Following the second 45mins exposure MISSED scores are 20.8% higher in cold than temperate and 27.8% higher in cold than hot.

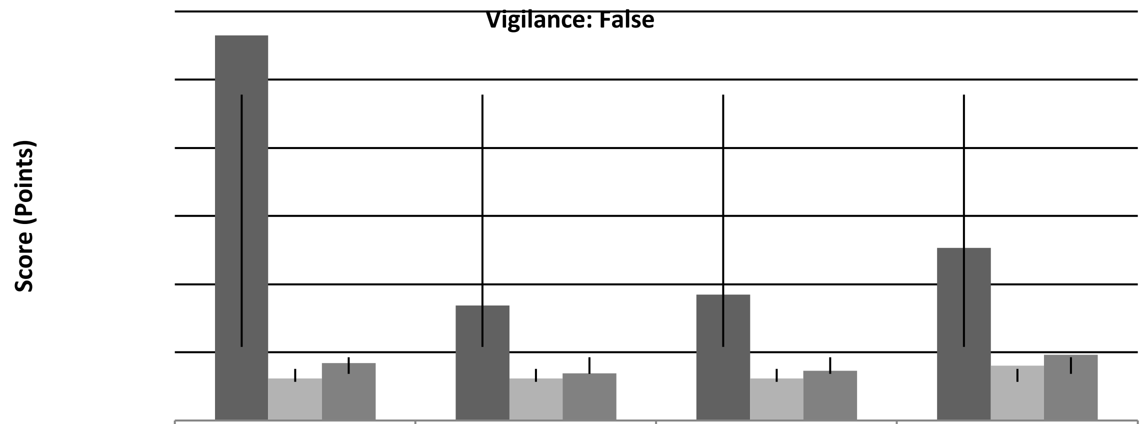


	0	45	45 (2)	90
Cold	7.46	8.61	9.84	10.15
Temperate	7.61	7.69	7.3	8
Hot	6.38	6	6.92	7.3

Figure 18. Mean (SD ±) Vigilance Miss scores at all time points. Miss scores gerenally were higher in the cold condition than temperate and hot although no significant differences were observed.

No main effect of condition was observed for FALSE scores during the vigilance task (F=4.409, P=0.062). There was not a main effect of time (F=0.720, P=0.418) or interaction

(F=0.666, P=0.438). FALSE scores were not significantly different between conditions (cold: 5.8 ±15.8; temperate: 1.3 ±1.4; hot: 1.6 ±1.8) (P=>0.05) (ES=Cold Vs. Temp: 3.2; Cold Vs. Hot: 2.3; Temp Vs. Hot: 0.2). But after the first 45mins exposure to FALSE scores were 66.7% higher in cold than temperate and 60.7% higher in cold than hot. Following the second 45mins exposure to cold FALSE scores were 68% higher in cold than temperate and 62% higher in cold than hot.



	0	45	45 (2)	90
Cold	11.3	3.38	3.69	5.07
Temperate	1.23	1.23	1.23	1.61
Hot	1.69	1.38	1.46	1.92

Figure 19. Mean (SD ±) Vigilance False scores. False scores were higher in the cold condition than temperate and hot conditions although no significant differences were observed.

5.3.Regression Analysis

Table 2. Regression analysis of cognitive performance; dual task and vigilance, and their associations with physiological responses.

	Dual Task		Vigilance	
Variable	**TARGET**	**FALSE**	**HIT**	**FALSE**
Rectal Temperature	0.798	0.816	0.366	0.787
Skin Temperature	0.001	0.002	0.026	0.001
Thermal Sensation	0.85	0.388	0.901	0.331
Heart Rate	0.638	0.252	0.869	0.401

Results of regression analysis indentified only skin temperature as an independent predictor of cognitive performance. Skin temperature was an independent predictor of tracking performance (Target) (Beta=1.179, t=3.699, P=0.001) and negative responses (FALSE) (Beta=-1.133, t=-3.248, P=0.002) during the Dual Task. Skin temperature was also an independent predictor of positive responses (HIT) (Beta=0.351, t=2.321, P=0.026) as well as negative responses (Beta=-0.664, t=-3.657, P=0.001) during the vigilance task.

With reference to the associated Beta values positive responses; increases in tracking performance (Target) (Beta=1.179) and Hit scores (Beta=0.351) increase with unit (°C) increase in skin temperature. Conversely negative responses; False (Beta=-1.133) (Dual Task) and False (Beta=-0.664) (Vigilance) increase with every unit (°C) decrease in skin temperature as indicated by their associated Beta values.

6.0.Discussion

The aim of the present investigation was to assess the decision making ability of goal line officials when exposed to various environmental conditions; cold (-5 °C, 40%RH), temperate (18 °C, 40%RH), and hot (30 °C, 40%RH). It was observed that exposure to cold conditions reduced cognitive processing and multiple facets of decision making ability. Exposure to cold reduced subjects ability to track stimuli leading to significantly worse tracking performance when compared to temperate (P= 0.011) (ES= 1) and hot (P=0.003) (ES= 1). While exposure to the heat increased subjects ability to respond correctly to stimuli when compared to cold (P= 0.025) (ES= 0.5). Although no other significant differences were observed in decision making performance, large percentage decrements were observed during exposure to cold conditions, with increases in MISS and FALSE scores during cold exposure. Previous literature report similar findings to that of the present study, observing reductions in cognitive performance during exposure to cold conditions (Shurtleff et al., 1994, Mahoney et al., 2007, Spitznagel et al., 2009). Such findings are also in line with the present study in regard to physiological data, with a reduction in cognitive performance coupled with reductions in Tre and Tsk and thermal sensation (comfort).

6.1.Data Interpretation- Mechanistic Analysis

HIT scores represent the correct judgement by a GLO of an infringement in and around the penalty area. Hit scores were significantly higher during the hot condition when compared to cold exposure (P= 0.025). Mean heart rate was higher during hot (82.1 ±13.9) when compared to temperate (70.8 ±11.7) (P=0.005), and cold (76.2 ± 10.8) although this was not significantly different.

The relationship observed during heat exposure between elevated heart rate and improved HIT scores may not be coincidental. Increased heart rate is an indicator of elevated levels of adrenaline (epinephrine) (Krahenbuhl, 1975), and as subjects were not exercising elevated heart rate cannot be attributed to the increase physiological strain experienced by the body during exercise in the heat. Increased levels of adrenaline can result in enhanced arousal, and improve cognitive performance (Krahenbuhl, 1975). Arousal induced enhancements in cognitive performance are attributed to the inverted U theory (Galloway and Maughan, 1997). The inverted U theory states that moderate levels of arousal are ideal for inducing optimal performance to a given task either cognitive or physical, to little or to much arousal leads to cognitive processes that may lead to deteriorated performance such as distraction (Krane, 1992). As subjects were stood in the heat their metabolic turn over will have been minimal, not significantly effecting endogenous temperatures, thus not inducing significant thermoregulatory response. As it was presumed thermoregulatory response activation was minimal during exposure to the heat it is likely that catecholamine (neurotransmitter) metabolism will not have been excessive, preserving neurotransmitters for cognitive function. It is possible that as norepinephrine was not required for stress response dopamine and epinephrine may have been prioritised; dopamine to be projected to the prefrontal cortex from the ventral tegmental area via the mesocortical projection to activate executive functions (Spitznagel et al., 2009) and, epinephrine to increase arousal, increasing heart rate (Brisswalter et al., 2002). The difference in heart rate between cold and hot was not significant ($P = 0.119$), this may lead one to assume that cognitive performance in the cold condition should have benefited from the same catecholaminergic enhancement experienced during the hot condition. Although the physiological strain experienced during the hot and cold condition was quite different; as subjects were stood still in the heat little sheer stress will have been experienced, yet the sheer stress experienced during the cold condition will have been considerably more, as subjects wore only t-shirt and shorts, similar to the uniform worn by UEFA GLO. As subjects suffered considerable reductions in core and skin temperature during exposure to the cold thermoregulatory responses; brown adipose tissue activation (non-shivering thermogensis), vasoconstriction, shivering, and increased metabolic rate will have undergone activation. All such responses require substantial amounts of norepinephrine to function; as a result norepinephrine may have been prioritised over dopamine as a survival response. So, it appears that heart rate was increased because of the up regulation in metabolic rate and physiological response to cold exposure.

Improved Hit scores during the hot condition were observed in association with improved thermal sensation scores; cold (1.3 $\pm$1), temperate (3.7 $\pm$0.4), hot (5.0 $\pm$0). The scores attained for both the cold and temperate conditions indicate thermal comfort below neutral, and may have had a negative effect on cognitive performance. This is supported by previous research reporting reductions in cognitive function following a decrease in thermal comfort, as described by reductions in skin temperature and thermal sensation scores. Similar findings were observed in the present study where a general trend developed; as T_c, T_{sk} and thermal sensation ratings increased through the conditions (cold: lowest; hot: highest) cognitive performance across the two tasks tended to improve, with an increase in positive responses (HIT scores and improved tracking performance) and a decrease in negative responses (FALSE AND MISS scores).

It would be expected that GLO make more correct decisions in hot conditions when compared other ambient conditions; particularly cold exposure. As GLO don't exercise they suffer minimal heat stress and thus thermoregulatory responses are not activated maximally. As a result the demand for norepinephrine is lower and dopamine can be prioritised for projection to the prefrontal cortex, which should enhance decision making performance.

Teichner (1958) suggests that reductions in cognitive performance may be due to environmentally induced distraction. As environmental conditions become more challenging changes in endogenous physiology and thermal comfort provide a opposing stimuli to the cognitive process and distracted subjects from the task at hand (Teichner, 1958).

Findings from the present study indicate that cognitive performance may be enhanced with improvements in thermal comfort through small increases in endogenous temperatures. Regression analysis from the current data indicates that cognitive performance is associated with changes in skin temperature. That is as skin temperature increases cognitive performance improves, equally as skin temperature decreases so does cognitive performance.

Thermal comfort is strongly associated with changes in skin temperature and thermal sensation scores (Gagge et al., 1967), although in the present study thermal sensation scores were not an independent predictor of cognitive performance. Findings of the regression analysis may provide the most rationale explanation for the reduction in cognitive performance during cold exposure. During cold exposure skin temperature and thermal sensation scores were significantly reduced when compared to temperate and hot conditions ($P<0.05$), indicating that thermal comfort had been negatively affected. It may be that cognitive performance shares a linear relationship with thermal comfort as described by the Beta values of the regression analysis. Reductions in cognitive performance: increases in False scores, were significantly associated with reductions in skin temperature (Dual task, Beta= -1.133; Vigilance, Beta= -0.664). These values indicate that for every degree (°C) reduction in skin temperature False scores will increase, thus cognitive performance suffers decrement. Conversely, Beta values (Dual Task, Tracking= 1.179; Vigilance, Hits: 0.351) indicate that for every degree (°C) increases in skin temperature positive responses increase, thus cognitive performance improves. Such findings fit well with the theory of distraction; as skin temperature, an independent predictor of cognitive performance, is tightly linked to thermal sensation it appears that as thermal comfort improves so does cognitive performance. Equally, as thermal comfort is reduced so is cognitive performance. This suggests that cold exposure provided a strong enough stimuli to distract subjects from the cognitive tasks at hand and that heat exposure may have been enough of a stimuli to improve performance but not any decrement.

Skin temperature suffered a marked decrease during cold exposure (24.5 $\pm$2.5 °C) when compared to temperate (29.4 $\pm$1.4) with heat exposure (33.2 $\pm$1.1) increasing skin temperature when compared to temperate. The effects of reducing thermal comfort on cognitive performance, and the possible improvement in cognitive performance through passive heating may be explained by maximal adaptability model (Hancock and Warm, 2003) (See figure 5). Similar to the inverted U hypothesis it suggests that there is a level of stress that increases arousal to optimal levels which in turn improves cognitive performance (Hancock and Vasmatzidis, 2003). The model explains that as one moves further away from the comfort zone following exposure to a stressor ones psychological adaptability; the ability to manage stimuli and resources effectively, becomes negatively affected. It may be that cold exposure was too greater stimuli and caused subjects to fall out of the area of psychological adaptability into the area of dynamic instability where psychological processes do not function correctly. However, moderate passive heating may have been enough of a stressor to ensure subjects remained in the comfort zone maintaining cognitive function at optimal capacity, as observed in the increased HIT rates and tracking scores in the hot condition compared to temperate and cold.

6.2.Cognitive Performance during Environmental Stress: Causes of Decrement

GLO are exposed to cold conditions (environmental stress) for the vast majority of UEFA club cup competitions, and must be able to make correct decisions correctly. As the decisions made by GLO can affect the overall outcome of a match any decrement observed in cognitive performance may negatively effect the outcome of a fixture, which could lead to a team being knocked out of a competition. This considered the physiological cause of the cold induced decrements observed in the present study and experienced by GLO in UEFA competitions must be considered.

It has been hypothecated that the cold induced reduction in decision making performance may be a result of increased neurotransmitter metabolism (Mahoney et al., 2007). Neurotransmitters support numerous physiological responses within the body, including cognition (Deijen and Orlebeke, 1994), activating physiological responses to a change in the ambient environment (Briand et al., 2007) and muscle recruitment (Brisswalter et al., 2000).

Humans have a finite ‘pool’ of neurotransmitters in which they can distribute to all physiological and cerebral functions required, such neurotransmitters include; epinephrine, norepinephrine, serotonin and acetyl-choline (O'Brien et al., 2007a), as the synthesis of neurotransmitters is rate limited by the substances which catalyse neurotransmitter production (Cropley et al., 2006). Thus, when large amounts of neurotransmitters are required by various systems, the evolutionary response of humans prioritises responses and mechanisms required to ensure survival (Piantadosi, 2003) .

A prime example of this trade off occurs during exposure to extreme environments. Neurotransmitters, dopamine and norepinephrine are closely linked in usage and synthesis (Briand et al., 2007). Dopamine is synthesised via the dopaminergic pathway which involves the conversion of tyrosine to L-DOPA and the conversion of L-DOPA to dopamine (Cohen et al., 2002). Norepinephrine is not synthesised through its own pathway, instead dopamine is converted into norepinephrine by dopamine B-Hydroxylase (Savitz et al., 2006). This pathway is continued further by converting norepinephrine into epinephrine through the action of phenylethanolamine N-methyltransferase (Savitz et al., 2006). Norepinephrine is required to execute a number of functions both physiological and cerebral functions and is required to activate thermoregulatory functions such as, shivering, vasoconstriction and non-shivering thermogensis (Romanovsky, 2007). When, for example, humans are exposed to extreme cold the evolutionary survival response will prioritise neurotransmitters for functions that will ensure physiological integrity. Thus, the majority of dopamine which is required for higher cognitive functions within the prefrontal cortex will be 'sacrificed' and converted into norepinephrine, which can be projected to activate thermoregulatory responses (Piantadosi, 2003). Previous research (O'Brien et al., 2007a) observed reductions in core temperature are associated with reductions in executive functioning during exposure to extreme cold. Although plasma concentrations of neurotransmitters were not measured, it was hypothesised that an increase in neurotransmitter metabolism was responsible for the cognitive decrement. Thus, it seems plausible that the observed reduction in Tc and Tsk during cold exposure in the present investigation may offer inferential evidence that the prioritisation of neurotransmitters for thermoregulatory integrity lead to a decrease in cognitive function.

6.3. Cognitive performance during Environmental Stress: Ergogenic Aids

Considering the reduction in cognitive performance observed in the present study may have important external implications it would appear rational to consider ergogenic aids that may help ameliorate environmentally induced cognitive decrement.

6.3.1. Tyrosine

Tyrosine has been reported previously to have ergogenic effects of cognitive (Banderet and Lieberman, 1989, Deijen and Orlebeke, 1994, Deijen et al., 1999, Harmer et al., 2001, Mahoney et al., 2007) and physical performance (Tumilty et al., 2011, Lieberman et al., 2005) during exposure to environmental stress, including; cold, heat, and hypoxia.

Tyrosine is an integral part of the dopaminergic pathway it synthesises dopamine, norepinephrine and epinephrine (MISSALE et al., 1998). When exposed to environmental stress evolutionary survival mechanisms required to maintain physiological integrity are prioritised are proffered the neurotransmitters (primarily norepinephrine) to function, sacrificing cognitive function and exercise performance, which require norepinephrine for activation, as they are not deemed important enough to survival of the animal (Piantadosi, 2003). As humans (mammals in general) only have a finite 'pool' of norepinephrine at their disposal when exposed to environmental stress significant decrements in cognitive and physical performance are observed in a condition dependant manor.

This considered it would appear beneficial to up-regulate the synthesis of norepinephrine and the other important neurotransmitters dopamine and epinephrine. This in turn should increase the availability of neurotransmitters maintaining the performance of cognitive and physical performance when physiological survival mechanisms are activated simultaneously.

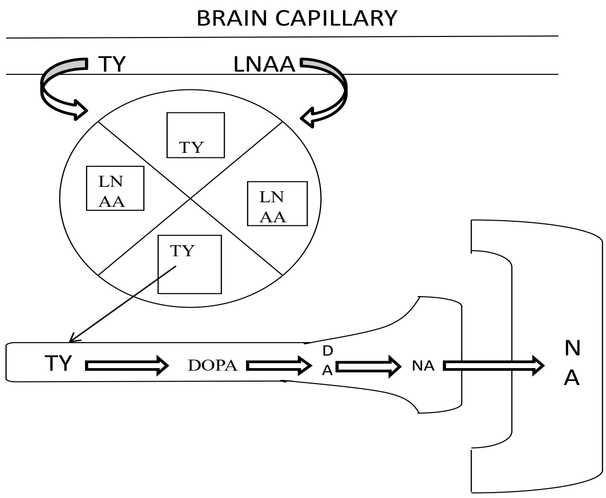


Figure 21. Movement of tyrosine (TY) from a brain capillary competing with long neutral amino acids for carrier positions into a brain neuron. Tyrosine is then converted to L-DOPA (DOPA), dopamine (DA), and norepinephrine (NA).

Tyrosine and Tyrosine hydroxylase are rate limiters for the dopaminergic pathway (CANNON and NEDERGAARD, 2004) and enhancements of tyrosine concentrations are hypothesised to improve human performance, both thermoregulatory and exercise performance, when exposed to environmental stress (O'Brien et al., 2007a).

Tyrosine supplementation up-regulates the synthesis of dopamine and so up-regulates the synthesis of norepinephrine and epinephrine (Mahoney et al., 2007). As exposure to environmental stress and stress in general increases the metabolism of neurotransmitters (Meeusen and Roelands, 2010), improvements in neurotransmitter availability during exposure to stress should ameliorate the decrements observed in exercise and cognitive performance without tyrosine supplementation.

Tyrosine supplementation may have a multi-faceted role in aiding GLO in cold conditions. As tyrosine supplementation up regulates the production of dopamine and norepinephrine a larger pool of neurotransmitters will be available to delegate the required concentrations to both physiological and cognitive. Thus the decrement in cognitive performance experienced by GLO should be minimised if not entirely ameliorated.

6.3.2. Pre-Heating

As a cold induced reduction in endogenous temperatures leads to cognitive decrement (Mäkinen et al., 2006, Enander, 1987) it may be beneficial to preheat the body prior to cold exposure. It appears that cognitive performance suffers decrement when there are considerable reductions in bodily temperatures from that of resting levels (Muller et al., 2012). Increasing endogenous temperatures prior to cold exposure should create a larger gradient between resting endogenous temperatures, and the temperatures required to cause cognitive decrement (Kruk et al., 1990). A method as simple as an exercise warm-up has been shown to benefit thermoregulatory performance prior to cold exposure. Kruk et al. (1990) employed a 10 minute warm up at 40% VO^2max in cold conditions (5 ºC) compared to no warm up (rest) in the same conditions. It was reported that a warm up in cold conditions offset reductions in total body temperature and feelings of reduced thermal sensation during cold exposure following the warm up. This simple intervention increased core temperature prior to cold exposure increasing the temperature difference between starting temperatures and that of thermoregulatory ‘overload’ and thermal discomfort (Kruk et al., 1990). Such an intervention could be easily employed by GLO as there officiating colleagues conduct a warm up prior to every match. A warm up may offset the cold induced thermal discomfort experienced during cold exposure when GLO are static, which in turn may minimise the effects of distraction. Similar results were reported by Flouris et al. (2006) who employed a whole body heating suit. Subjects were exposed to extremely cold conditions (-20 ^{o}C) with either i) no heating, ii) preheating or iii) heating throughout protocol. It was observed that preheating improved hand dexterity tasks that required significant cognitive resources when compared to no heating (Flouris et al., 2006). Yet heating throughout the entire protocol improved performance further as the effects of preheating alone deteriorated over time (Flouris et al., 2006). Similarly to the warm up intervention pre-heating using a water filled suit could be used by GLO prior to cold exposure to increase bodily temperatures which may offset any detrimental reduction in temperatures. It may also be possible to employ both types of pre-heating by completing a warm-up followed by use of the water filled suit immediately prior to a match which should blunt any reduction in endogenous temperatures following completion of the warm up.

6.4.Limitations

The very nature of the environmental conditions replicated in the present study posed methodological limitations that could not be entirely ameliorated. Firstly, environmental conditions were replicated in an environmental chamber, and while reliability testing is regularly carried out on the environmental chamber to ensure it is fully calibrated and able to maintain a constant desired temperature there are regularly fluctuations in ambient temperature and humidity. Such fluctuations are taken into account when analysing data and such fluctuations tend to account for any anomalies found in data recordings.

The timing of the cognitive tests also posed and issue with regards to external validity. The cognitive tests in the present study were structured so that all subjects complete cognitive tests per condition at exactly the same time. GLO are required to make snap judgements on incidents at any given time during a match, not at scheduled intervals which was the case in the present study. The scheduled intermittency of the cognitive tests in the present study may not reflect the true requirements of GLO. GLO are expected to remain fully focused throughout a 90 minute match so they are able to correctly judge and infringement, where as subjects in the present study were not required to maintain concentration for the whole 90 minute protocol; only at the beginning and end of each half. Future research following a similar protocol may choose to enforce cognitive tests at more sporadic intervals.

The nature of the cognitive tests must also be considered. The subjective nature of soccer infringements makes using such stimuli as a cognitive test difficult, this lead the present study to employ objective cognitive tests. The Psyche Software Package is a validated method of cognitive assessment, but it lacks applicability to soccer specific decision making. Future research should consider employing soccer specific decision making cognitive assessment, yet as previously mentioned the subjective nature of soccer infringements makes this difficult.

7.0.Conclusions

The present study through the synergistic use of various data analysis techniques (ANOVA, Percentage of Difference, Means (SD $\pm$), and regression analysis) reported the detrimental effect of extreme cold exposure on the decision making performance of GLO. As such conditions are regularly experienced in UEFA competitions the findings of the present study deserve serious consideration. The decisions made by GLO can affect the result and outcome of a cup fixture having a significant financial and social impact on a European club.

The findings of the present study present a rationale for the employment and use of ergogenic aids to maintain/enhance GLO performance in extreme cold to minimise the occurrence of incorrect decisions being made. Equally, the decrements observed provide a strong rationale for the employment of goal line technology in favour of GLO, as technology negates the issue of environmental stress and minimises the occurrence of human error.

Finally, future research may consider the use of soccer specific cognitive tasks employed at random time points to reflect the attention and cognitive requirements of GLO more closely. The use of high standard soccer match officials will also improve the external validity future research; as their response to soccer specific cognitive tasks should be better than that of a more general sample population.

8.0.References

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9.0.Appendices

Appendix A) Consent Form

Appendix B) Information Sheet

Appendix C) Par-Q and You: Readiness for Physical Activity Form

Appendix A

9.1.CONSENT FORM

<u>TO BE COMPLETED BY PARTICIPANT</u>

NAME:…………………………………………………(Participant)

I have read the Information Sheet concerning this project and understand what it is about. All my further questions have been answered to my satisfaction. I understand that I am free to request further information at any stage.

I know that:

- My participation in the project is entirely voluntary and I am free to withdraw from the project at any time without disadvantage or prejudice.

- I will be required to attend testing in the sport and exercise science laboratories on 3 separate occasions to complete the project.

- As part of the study I will have to

  - Undergo exposure to various ambient temperatures (-5^{o}C, 18^{o}C, 30^{o}C)
  - Carry out 90 minutes of small lateral movements while exposed to various environmental conditions.

- Carry out a cognitive performance tests (vigilance & peripheral vision) prior to and after the 90 minutes protocol, as well as during the half time break.
- Have skin and core (rectal) temperature measured throughout the testing, for research and safety purposes.
- Have heart rate monitored throughout testing.
- Give an indication of rate of perceived exertion and ratings of thermal sensation throughout testing.
- Provide a urine sample for testing pre/post each bout of testing.
- Ingest a either a caffeine supplement (<6mg/kg) or a placebo prior to all testing conditions.
- Have blood pressure measured.

\- I am aware of any risks that may be involved with the project.

\- All information and data collected will be held securely at the University indefinitely. The results of the study may be published but my anonymity will be preserved.

Signed:………………………………… (Participant) Date: ………………

Appendix B

9.2.Information Sheet

University of Bedfordshire

Department of Sport and Exercise Sciences

Bedford Campus

Polhill Avenue

Bedford

MK41 9EA

Dear Participant,

Thank you for showing an interest in participating in this UEFA research. Please read this information sheet carefully before deciding whether to participate. If you volunteer we thank you for your participation. If you decide not to take part there will be no disadvantage to you of any kind and we thank you for considering our request.

What is the aim of the project?

The purpose of the study is to assess officiating performance of a football goal line official during exposure to extreme environmental conditions (-5ºC & 30ºC) that are commonly experienced by match officials around Europe. An intervention (caffeine) will also be employed during experiment 2 in an attempt to reduce the effects of extreme hot and cold on your body's ability to regulate temperature and your decision making capacity.

What type of participant is required?

Participants must be 18-45 years of age or older, male, and in possession of a basic refereeing qualification. Participants must also be able to complete a full 90 minute match of officiating as we need you to perform a running protocol (we will familiarise you to this).

What will the participant be required to do?

Participants will be required to attend the Sport Science Laboratories at the University of Bedfordshire's Polhill Campus on 3-5 occasions (depending on availability). Participants will be required to wear their official refereeing uniform, and abstain from alcohol for 24 hours and caffeine for 12 hours before each bout of exercising.

All experiments will be carried out in varying environmental conditions: hot (30^{o}C), neutral (18^{o}C), and cold (-5^{o}C). During experiment 2 participants will have their blood pressure measured and then be required to ingest either a caffeine supplement or placebo, although this will not be carried out during experiment 1. The subject will fill out a PAR-Q form (to confirm if the subject has any illnesses or conditions). The subject will then provide a urine sample (in a private room). Then the subject will then insert a sterile, flexible and small rectal thermometer 10cm past the anal sphincter (in a private room), put on a heart rate monitor, and skin thermometers. A blood sample will then be required from a vein in your arm. Your subjective ratings of how hard the exercise feels (perceived exertion) and how hot or cold you feel (thermal sensation) will be asked of you throughout testing.

Next, you will enter the environmental chamber, that allows us to re-create different environments. You will complete a mental vigilance and peripheral vision test (cognitive tests) on a computer. The participant will then remain in the chamber, in the environmental conditions required for that particular bout of test (-5^{o}C, 18^{o}C or 30^{o}C) for 45 minutes, during which time you will be asked to make small lateral movements. Then participant will then leave the chamber for 15 minutes (half time rest period), and complete the cognitive tests again. At the end of 15 minutes the subject will again enter the environmental chamber and repeated the process to simulate the second half of football. Then the participant will complete the cognitive tests again. On completion of these the participant will leave the chamber and have a blood sample taken, as well as provide a urine sample. After all measurements and tests are completed you will be asked to remain under the supervision of the researcher while your recovery is monitored. When you have fully recovered the researcher will remove your heart rate monitor, and skin thermometers, you will then remove and safely dispose of your rectal thermometer (in private) in a biological waste bin which will be provided.

What are the possible risks of taking part in the study?

When exposed to extreme environmental conditions you may experience some cramping or light headedness due to the heat, or shivering due to the cold. However, this is not expected to be any different to the normal temperature variation that occurs naturally. We have full safety and ethical clearance and are trained in first aid. We are experienced in environmental physiology and fully equipped to deal with any issues.

What if you decide you want to withdraw from the project?

If, at any stage you wish to leave the project, then you can without given explanation. There will be no disadvantage to yourself should you wish to withdraw.

What will happen to the data and information collected?

Everyone that takes part in the study will receive their own results for the tests that they complete for your own personal development and understanding. All information and results collected will be annonymised and held securely at the University of Bedfordshire and will only be accessible by the project team. Results of this project may be published, but any data included will in no way be linked to any specific participant. Your anonymity will be preserved.

What will I gain from taking part?

Should you choose to take part you will be entitled to a full assessment of your fitness, this includes scientific measurement of your maximal oxygen uptake (aerobic fitness/VO_{2max}), body composition testing (body fat/muscle %), as well as advice on improving your level of fitness and physical well being. Testing of this nature is usually carried out as consultation work by the University for Professional Bodies and costs approximately ***£300***. Should you choose to take part in the study you will be offered this testing completely ***free*** of charge.

Questions are always welcome and you should feel free to ask either ourselves (Samuel Watkins/Natalie Fitch) or Professor John Brewer any questions at anytime. See details below for specific contact details.

If you are interested in taking part in the project and would like to receive more details about the studies please send and email to either:

Samuel Watkins *07903275091*

Email: Samuel.watkins@beds.ac.uk

Professor John Brewer

Email:John.Brewer@beds.ac.uk

Natalie Fitch *07533822337*

Email: Natalie.fitch@beds.ac.uk

Department of Sport and Exercise Sciences,

University of Bedfordshire

Bedford Campus,

Polhill Avenue, Bedford

Appendix C

9.3.Par-Q and You

Physical Activity Readiness Questionnaire - PAR-Q (Revised - July 2007)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly : Check YES or NO.

YES	NO	
☐	☐	Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor?
☐	☐	Do you feel pain in your chest when you do physical activity?
☐	☐	In the past month, have you had chest pain when you were not doing physical activity?
☐	☐	Do you lose your balance because of dizziness or do you ever lose consciousness?
☐	☐	Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?
☐	☐	Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
☐	☐	Do you know of <u>any other reason</u> why you should not do physical activity?

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want - as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to <u>all</u> PAR-Q questions, you can be reasonably sure that you can :

- start becoming much more physically active - begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal - this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

➔ **DELAY BECOMING MUCH MORE ACTIVE:**

- if you are not feeling well because of a temporary illness such as a cold or a fever - wait until you feel better; or
- if you are or may be pregnant - talk to your doctor before you start becoming more active.

Please note: If your health changes so that you then answer "YES" to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

<u>Informed Use of the PAR-Q</u>: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

Signature:______________________ Identity Document No.:______________________

Name:______________________ Date:______________________

Signature of Parent or Guardian:______________________ Witness:______________________
(for participants under the age of majority)

Note: 1.The information provided on this form will only be used for the application for use of Leisure and Cultural Services Department's Fitness Rooms and enrolment of recreation and sports activities. For correction of or access to personal data collected by means of this form, please contact staff of the enrollment counter/district.

2.If you answer "yes" to one or more questions in the "PAR-Q & YOU", your physical condition may not be suitable for taking part in the activity concerned. For safety's sake, you should consult a doctor in advance and produce a medical certificate upon enrolment or hire of fitness equipment to prove that you are physically fit for taking part in the activity. If you fail to produce a medical certificate, you must submit the completed Declaration upon enrolment or hire of fitness equipment.

This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.