Applied Ergonomics 62 (2017) 150–157

Contents lists available at ScienceDirect

Applied Ergonomics

journal homepage: www.elsevier.com/locate/apergo

Effects of heat stress on risk perceptions and risk taking

Chu-Hsiang Chang, PhD [a,*], Thomas E. Bernard, PhD [b], Jennifer Logan, MPH [b]

[a] *Department of Psychology, Michigan State University, USA*
[b] *Department of Environmental and Occupational Health, University of South Florida, USA*

ARTICLE INFO

Article history:
Received 28 October 2015
Received in revised form
20 February 2017
Accepted 24 February 2017
Available online 6 April 2017

Keywords:
Heat stress
Risk behavior
Risk evaluation

ABSTRACT

Exposure to extreme heat at work is a serious occupational hazard, as exposure can result in heat-related illnesses, and it has been linked to increased risk of accidents and injuries. The current study aimed to examine whether heat exposure is related to changes in individuals' psychological process of risk evaluation, and whether acclimatization can mitigate the effect of heat exposure. A study with quasi-experiment research design was used to compare participants' risk perceptions and risk-taking behaviors at baseline, initial exposure to heat, and exposure after acclimatization across male participants who were exposed to heat ($N = 6$), and males ($N = 5$) and females ($N = 6$) who were in the control group who were exposed to ambient temperature. Results show that participants perceived the same risky behaviors to be less risky ($p = 0.003$) and demonstrated increased risk-taking behaviors ($p = 0.001$) after initial heat exposure. While their risk perceptions returned to baseline level after acclimatization, their risk-taking behaviors remained heightened ($p = 0.031$). Participants who were not exposed to heat showed no significant fluctuation in their risk perceptions and risk-taking. Our findings support that risk-related processes may explain the effects of heat exposure on increased accidents and injuries beyond its direct impact on heat-related illnesses.

1. Introduction

Exposure to extreme heat that is either due to higher ambient temperature in the work environment (e.g., outdoor labors) or from performing the job tasks (e.g., wielders) is considered a physical occupational hazard (National Institute for Occupational Safety and Health [NIOSH], 2016). This exposure can directly result in workers suffering from heat stress, or heat-related illnesses that range from mild irritations such as heat rash or cramps to serious conditions such as heat exhaustion. Without emergency medical attention, heat stroke, the most severe form of heat stress, can lead to death or permanent disability. For example, between years of 1992 and 2006, a total of 423 occupational fatalities from exposure to environmental heat were reported in the United States (Center for Disease Control and Prevention, 2008).

Moreover, heat exposure has also been considered as a threat to workers' safety. Research has demonstrated a linkage between heat exposure to increased rate of unsafe behaviors (Ramsey et al., 1983) and acute injuries (Fogleman et al., 2005; Garzon-Villalba et al., 2017). The slipperiness of sweaty palms, the fogging of safety equipment due to heat, and impaired physical performance are often blamed for such increases (NIOSH, 2016). In addition, research has shown that heat may increase individuals' irritation and hostility levels (Anderson, 2001), as well as their ability to stay alert or concentrated (Hancock and Vasmatzidis, 2003). These psychological variations may cause workers to overlook safety procedures or to divert attention from hazardous tasks. Unfortunately, other than cognitive, psychomotor, and perceptual performance such as reaction times or vigilance (see Hancock and Vasmatzidis, 2003 for a review), the psychological mechanisms through which heat exposure may influence workers' safety practices have not received much research attention. In addition, while it has been well-established that heat acclimatization improves the physiological responses to heat exposure, equivocal evidence exists for whether or how acclimatization may impact participants' psychological functioning (Gaoua, 2010).

One of such overlooked psychological processes is individuals' risk-related attitudes and behaviors. Considering the effects of heat exposure on individuals' risk perceptions and risk-taking is important for three reasons. First, when employees choose to ignore safety practices at work, such behavior can be conceptualized as a domain specific (i.e., health and safety) risk-taking

* Corresponding author. Department of Psychology, 346 Physics Road, Michigan State University, East Lansing, MI 48824, USA.
E-mail address: cchang@msu.edu (C.-H. Chang).

http://dx.doi.org/10.1016/j.apergo.2017.02.018
0003-6870/

behavior. Based on the principle of specificity (Ajzen and Fishbein, 1977), theory of planned behavior purports that a domain-specific attitude (i.e., attitudes about health and safety risks) is likely to be the best predictor for employees' health and safety risk-taking behavior. As such, changes in health and safety risk perceptions may help explain how heat exposure relates to employees' risky behaviors, and the resulting accidents, injuries, and even fatalities, at work. Next, understanding the risk-related mechanisms underlying the heat exposure and employees' behaviors at work may help identify additional intervention opportunities to prevent heat-related accidents at work. In this case, instead of managing the symptoms of heat exposure, interventions may target the psychological processes that are affected by the heat in order to reduce the risk for accidents and injuries. Finally, it is important to begin to explore if acclimatization has any effect on the risk-related psychological processes beyond the physiological adaptation. This research has been largely missing in the existent literature. Knowledge about this link may provide additional support for the importance of acclimatization practice.

The purpose of the current study is to examine if heat exposure alters individuals' risk-related psychological processes, including risk perceptions and risk-taking behaviors, and whether effects of heat exposure changes due to acclimatization. We will integrate the maximal adaptability model (Hancock and Warm, 1989), which explains the effects of heat exposure on individuals' cognitive performance, with the risk-return framework (Sarin and Weber, 1993) to hypothesize effects of heat exposure on individuals' risk perceptions and risk-taking attitudes after the initial and acclimatized exposures. Results from a quasi-experiment will be used to evaluate the proposed hypotheses.

1.1. Heat exposure and cognitive performance: the maximal adaptability model

Heat exposure can lead to various physiological responses, such as increased metabolic rate and body temperature, and physical reactions, such as reduced physical capabilities to perform strenuous tasks (Ahasan et al., 2002). Heat exposure may also impact individuals' cognitive performance. The maximal adaptability model (Hancock and Warm, 1989) describes how heat exposure taxes individuals' finite attentional coping resources that can be deployed to respond to environmental demands. When individuals are in a benign, nonstressful environment, their physiological and psychological functioning is within the normative zone, which requires minimum coping effort. As the environment becomes more demanding (e.g., prolonged exposure to heat, exposure to higher heat intensity), more attentional coping resources are necessary in order to maintain their cognitive functioning. Individuals may cope with initial heat exposure successfully by mobilizing resources, thereby maintaining or even enhancing their cognitive performance. However, as individuals continue to deploy energy to cope with the heat exposure, their attentional resources are eventually drained, thus pushing them outside of boundary of maximal psychological adaptability, and their cognitive performance is likely to deteriorate exponentially.

Indeed, empirical research has shown that heat exposure affects individuals' cognitive functioning differently depending on the type of cognitive tasks performed. Faervik and Reinertsen (2003) exposed their participants to three separate temperature variations (i.e., cold, warm, and hot) for 3 h, and observed their performance on a vigilance test and a reaction task to rapidly changing visual and acoustic stimuli. While participants' performance to the reaction task did not vary based on the heat exposure conditions, their accuracy decreased significantly when they were in the hot condition. Similarly, Vasmatzidis et al. (2002) observed that tasks that required visual perceptual input and manual response output were more sensitive to the effects of heat exposure, whereas tasks that require working memory processing capacity (e.g., memory search) were less affected.

The duration and intensity of the exposure and participant characteristics may also moderate the effects of heat on individuals' cognitive performance. Performance on psychomotor tasks may improve after the initial exposure (Gaoua, 2010). Meta-analytic results also supported the general trend that performance deteriorated more with longer exposure (up to 3 h; Hancock et al., 2007). In addition, exposure to different temperatures was associated with different performance detriments (Hancock et al., 2007). Finally, participants' demographic variables (e.g., sex) and acclimatization experiences may also impact how heat exposure affect their psychological functioning (Gaoua, 2010). These results suggest the importance of controlling for these extraneous factors when investigating psychological effects of heat exposure.

1.2. Risk return framework

The risk return framework suggests individuals' perceived risk attitude for an option is determined by the expected benefits and the riskiness of the option (Weber, 1998). Based on this framework, the context or domain in which the behavioral option resides can have meaningful effects on individuals' perceived risk attitudes for the action (Weber et al., 2002; Weber and Milliman, 1997). Interestingly, while the perceived riskiness of the options appears to change across domains, perceived riskiness of the behavior significantly predicted individuals' intention to engage in the target behavior, regardless of the domains (Weber et al., 2002). Thus, the current study will focus on the perceived riskiness of a specific domain—health and safety, as this domain corresponds to the workplace accident and injuries.

Three primary determinants of perceived riskiness of a given option are commonly discussed: probability of the consequence, severity of the consequence, and affective responses (e.g., Oglethorpe and Monroe, 1994; Leventhal et al., 2003). Perceived risk for a course of action increases if individuals believe that the probability of the action leading to a negative outcome is high and uncontrollable (Kaptein et al., 2007; Oglethorpe and Monroe, 1994). In addition, if they can readily recall the negative consequences of the behavior, and these consequences are immediate and nonreversible, this information increases the perceived outcome severity and thus the perceived riskiness of the behavior (Oglethorpe and Monroe, 1994). Finally, if the behavioral option or the potential consequences elicit strong, negative emotional reactions (Kaptein et al., 2007), these anticipatory affective responses increase the perceived riskiness of the behavior. Studies have supported that individuals consider a behavior riskier when they perceived the frequency of its negative consequences to be higher, more severe, and less controllable (e.g., Harris et al., 2008; White et al., 2004). Those who experience more negative affect such as anxiety, depression, and guilt (e.g., Ajcardi and Therme, 2008; Becker-Olsen and Briones, 2009; Gerend et al., 2004; Yao and Liao, 2011) tend to perceive a behavior to be risky.

We propose that when individuals are exposed to heat, their risk perceptions of behavioral options related to health and safety may decrease, thereby making them more likely to engage in risky behaviors. Heat exposure may alter the risk perceptions of the health and safety behaviors as it changes individuals' assessment of the probability and severity of the possible negative consequences associated with such behaviors. For example, although studies have shown that individuals' working memory function is relatively intact when exposed to heat (Vasmatzidis et al., 2002), studies have shown that individuals have impaired long-term memory functioning (i.e., encoding and retrieving) when exposed to heat (Curley and Hawkins, 1983). Information related to the potential negative consequences of the behavioral options may become less accessible or salient during heat exposure, leading individuals to underestimate the probability and severity of the negative outcomes. In addition, individuals who are exposed to heat are expected to expend attentional coping resources in order to maintain the same level of psychological functioning (Hancock and Warm, 1989). As a result, they may not have adequate mental resources to carefully evaluate the behavioral option in question, and rely on heuristics when judging the riskiness of the option. In this case, optimistic bias (Weinstein, 1982), which refers to the general belief that people are less at risk and more competent than others (e.g., DeJoy, 1999) may lead individuals to misjudge the controllability, likelihood, and severity of outcomes of their health and safety related behaviors. As individuals shift their perceived riskiness of the health and safety behavioral options down (i.e., considering them as less risky), they are more likely to engage in risky behaviors when exposed to heat. Interestingly, animal research results suggested that heat stress induced an increase in jumping escape behavior despite the negative reinforcement shock of the floor underneath the rats in the experimental condition (Harikai et al., 2004). Taken together, we propose the following hypotheses:

Hypothesis 1: There will be a decrease in risk perceptions for health/safety-related behavioral options after initial heat exposure compared to the baseline.

Hypothesis 2: There will be an increase in risk-taking behaviors after initial heat exposure compared to the baseline.

As mentioned earlier, effects of heat exposure on some psychological functioning appeared to vary depending on the acclimatization. Some research suggested that acclimatized participants performed better on complex tasks that required psychomotor skills (e.g., Radakovic et al., 2007). On the other hand, others suggested that even with acclimatized participants, skill acquisition was still impaired (e.g., Curley and Hawkins, 1983). It is possible that acclimatized individuals may have enough attentional resources to carefully evaluate the health and safety behavioral options, and their perceived riskiness of these options and their risk-taking behavior may be minimally affected by heat exposure. It is also conceivable that acclimatized individuals may still show impaired judgment and increased tendency for risk-taking. As such, we propose the following research questions:

Research question 1: Will acclimatization mitigate the effect of heat exposure on risk perceptions for health/safety-related behavioral options?

Research question 2: Will acclimatization mitigate the effect of heat exposure on risk-taking behaviors?

2. Methods

2.1. Participants

Seventeen participants (11 males and 6 females) ages between 20 and 40 participated in the study. Six male participants were in the experimental group for heat exposure, and the remaining participants were in the control group (5 males and 6 females). Participants were recruited from students enrolled in a large, southeastern university in the United States and they received $20 per study session in exchange for their participation. Participants in the experimental group were medically screened to ensure they were physical fit enough to go through the experiment.

2.2. Procedure

Because participants must be cleared by a thorough medical examination to be considered as fit prior to the heat exposure sessions, it is not possible to randomly assign participants to the different conditions. We therefore assigned the first six male participants who passed the medical examination to the experimental condition. In order to ensure that participants in the experimental and control groups were equivalent, we first assessed participants' dispositional characteristics that may be relevant to their risk perceptions and risk-taking behaviors to ensure that they are similar on those traits. In particular, participants completed measures of dangerous thrill-seeking, impulsive thrill-seeking, and calculated thrill-seeking and their scores were compared to see if there were systematic differences between experimental versus control groups. Results indicated that participants were not significantly different on the dangerous thrill-seeking ($F_{(2,14)} = 0.76$, $p > 0.05$), impulsive thrill-seeking ($F_{(2,14)} = 0.10$, $p > 0.05$), and calculated thrill-seeking ($F_{(2,14)} = 1.46$, $p > 0.05$). As such, participants across groups were similar in the traits that were related to the risk perceptions and risk-taking behaviors, and any observed differences in risk perceptions and risk-taking behaviors between the conditions cannot be attributed to inherent differences between the participants.

During the experimental session, participants in the experimental group were exposed to heat stress at 50 °C and 20% relative humidity for 2 h a day, five consecutive days. While in the heat chamber, they walked on the treadmill at a specific speed and grade that is estimated based on their body weight to achieve the metabolic rate of 160 W/m^2. Participants were provided with water or Gatorade® based on their preference.

They completed the focal measures of risk perceptions and risk-taking behaviors at three times: Baseline (prior to heat stress exposure on day 1), post initial exposure (1-h into the session on day 1) and post acclimatized exposure (1-h into the session on day 5). Control variables of traits were assessed at the baseline only.

For participants in the control group, they completed all the measures in a regular, temperature-controlled laboratory room at three different times. Their baseline measure, which included the focal risk assessment and control variables, was taken on day 1 upon the arrival of the laboratory. After the baseline measures, they were instructed to perform some leisure activities (e.g., surfing the internet, reading) of their choice for 1 h. They then completed the time 2 (akin to the post initial exposure) assessment. Participants came back to the same laboratory five days later, and they completed the time 3 assessment (akin to the post acclimatized exposure) after 1 h of leisure activities of their choice.

2.3. Measures

2.3.1. Sensation-seeking as control variables

To ensure that participants in the experimental and control groups were equivalent on traits that have been shown to relate to risk perceptions and risk-taking behaviors, participants reported their sensation-seeking level using a three-dimensional scale developed by Hoyle et al. (2002) using a 5-point Likert response format (1 = Strongly Disagree; 5 = Strongly Agree). The 10-item dangerous thrill-seeking scale assessed whether individuals prefer being in a threatening situation ($\alpha = 0.77$). An example item is "I like to do frightening things." The 10-item impulsive thrill-seeking scale assessed whether participants tend to behave in a spontaneous manner ($\alpha = 0.92$). An example item is “I do crazy things.” Finally, the calculated thrill-seeking scale asked participants to indicate whether they tend to take planned risk ($\alpha = 0.85$). An example item is “I face danger confidently.”

2.3.2. Risk perceptions

Participants' risk perceptions were assessed by the health/safety subscale of Domain-Specific Risk Taking Scale (DOSPERT) (Weber et al., 2002). DOSPERT-health/safety scale includes five items ($\alpha = 0.63$) that measured the individual's perceived riskiness of engaging in various behaviors related to their health and safety. Participants responded to the items using a 5-point Likert scale (1 = not at all risky, 5 = extremely risky). An example item is “Driving a car without wearing a seatbelt.” Before completing the baseline assessment, participants were told that there was no right or wrong answers to these statements. At the post exposure assessments, the statement was reiterated, and participants were also encouraged to respond based on how they felt about each item at the time of the administration, rather than trying to recall the answers that they have provided earlier.

2.3.3. Risk-taking behavior

Participants’ risk-taking behaviors were assessed by the Behavioral Analogue Risk Task (BART; Lejuez et al., 2002, 2003). The BART was designed to examine actual risky behavior. The task was presented on the computer in the heat chamber. Items on the computer screen included a small simulated balloon accompanied by a balloon pump, a reset button labeled *Collect $$$*, and a permanent money-earned display labeled *Total Earned*. The balloon increased in size by approximately 0.125 inches in all directions per click on the pump. With each pump, 5 cents were accrued in a temporary reserve (the amount of money in this reserve is never indicated to the participant). Due to the variable sequence, when a balloon was pumped past its individual explosion point, a “pop” sound effect would be generated from the computer. When a balloon exploded, all money in the temporary bank would be lost, and the next uninflated balloon will appear on the screen. The participant could cease pumping the balloon at any time and click on the *Collect $$$* button to transfer all of the money from the temporary bank to the permanent bank. A new total earned will be incrementally updated cent by cent.

After each money collection or balloon explosion, the participant's exposure to that specific balloon ended until a total of 10 balloons (i.e. trails) have been completed. Participants were not given any detailed information about the balloon explosion. They were told that the balloon may pop as early as the first pump or it may pop after it has filled the entire computer screen. The probability that the balloon would explode is set by constructing an array of *N* numbers. The number 1 indicated a balloon explosion and each pump were selected without replacement from the array. The balloons contain the integers 1–128. The probability that the balloon will explode on the first pump would be 1/128. With each successive pump, the probability increased until it was 1/1 (i.e. 100%). According to this algorithm, the average break point was 64 pumps. The adjusted average number of pumps, not including popped balloons, served as indicators for risk-taking behaviors.

At the onset of the task, participants were told, “Throughout the task, you will be presented with 10 balloons, one at a time. For each balloon you can click on the button labeled “Press This Button to Pump Up the Balloon” to increase the size of the balloon. You will earn 5 cents in a temporary bank for each pump. Since you will not know how much you have accumulated in your temporary account, you may stop pumping the balloon and click on the button labeled “Total Earned”. It is entirely your choice to determine how much you want to pump the balloon, but be aware it will eventually explode. The explosion point varies from one balloon to the next, ranging from the first pump to enough pumps to make it fill up the entire computer screen. If you have not clicked on “Collect $$$” before it explodes, you will move on the next balloon, losing all of your money in your temporary account. This will not affect how much money you have acquired in your permanent account. Your goal is to earn the maximum amount of money possible in your permanent bank at the end of the task”.

3. Results

3.1. Risk perceptions for health/safety behaviors

To examine the effects of heat exposure on participants' perceived riskiness of behavioral options related to health and safety, a 3 (between subject experimental conditions: experimental, control-male, control-female) x 3 (within subject measures: baseline, post initial exposure, post acclimatized exposure) mixed-design ANOVA was used. This mixed-design ANOVA takes into consideration that the three measures from the participants are nested within experimental conditions. Because the Mauchly's sphericity test for the within-subject factor was significant ($W = 0.57$, $p = 0.032$), we reported the Greenhouse-Geisser corrected ANOVA results below to account for the violation of sphericity assumption. No significant main effect was found for the experimental condition ($F_{(2,14)} = 1.72$, $p > 0.05$) or times of measurement ($F_{(1.40,19.61)} = 3.51$, $p > 0.05$). However, a significant interaction was found between the experimental condition and times of measurement ($F_{(2.80,19.61)} = 5.17$, $p = 0.010$). This suggested that depending on the experimental conditions, participants' risk perceptions for health/safety-related behavioral varied differently. Table 1 summarized the means and standard errors, and Fig. 1 illustrated the results at the individual level.

In particular, participants in the two control groups showed minimum changes across three assessment of risk perceptions (comparison of male control participants across three times: $F(_{(2,8)} = 0.58$, $p > 0.05$); comparison of female control participants across three times: $F(_{(2,10)} = 0.40$, $p > 0.05$)). On the other hand, the risk perceptions of participants in the heat exposure group varied significantly across the three times of assessment ($F_{(2,10)} = 13.47$, $p = 0.001$). The post-hoc comparison showed that after the initial heat exposure, participants' perceived riskiness for health/safety behavioral options reduced significantly compared to the baseline measure ($t_{(5)} = -5.30$, $p = 0.003$). However, participants' perceived riskiness increased from post initial exposure to post acclimatized heat exposure ($t_{(5)} = 5.51$, $p = 0.002$). Finally, there was no significant difference between perceived riskiness for health/safety behavioral options between baseline and post acclimatized exposure ($t_{(5)} = -0.83$, $p > 0.05$). Thus, Hypothesis 1 received support, such that heat exposure resulted in decreases in participants’ perceived riskiness of the health/safety behavioral options. Moreover, results suggested that acclimatization mitigated the effect of heat exposure on risk perceptions, which addressed Research Question 1.

3.2. Risk-taking behavior

A 3 (between subject experimental conditions: experimental, control-male, control-female) x 3 (within subject measures: baseline, post initial exposure, post acclimatized exposure) mixed-design ANOVA was also used to compare participants' risk-taking behaviors. Mauchly's sphericity test for the within-subject factor was not significant ($W = 0.88$, $p > 0.05$), suggesting that the sphericity assumption has been met. No significant main effect was

Table 1
Means and standard errors of risk perceptions for health/safety-related behavioral options across times in three conditions.

	Within-subject: Timing of measure		
	Day 1: beginning of the session	Day 1: Hour 1	Day 5: Hour 1
Between-subject condition: Heat exposure			
Heat exposure	4.00 (0.23)	3.07 (0.31)	3.80 (0.34)
Control: Male	3.28 (0.25)	3.24 (0.34)	3.02 (0.37)
Control: Female	3.93 (0.23)	4.00 (0.31)	3.87 (0.34)

Note: $N = 6$ for heat exposure condition, $N = 5$ for control: male condition, $N = 6$ for control: female condition.

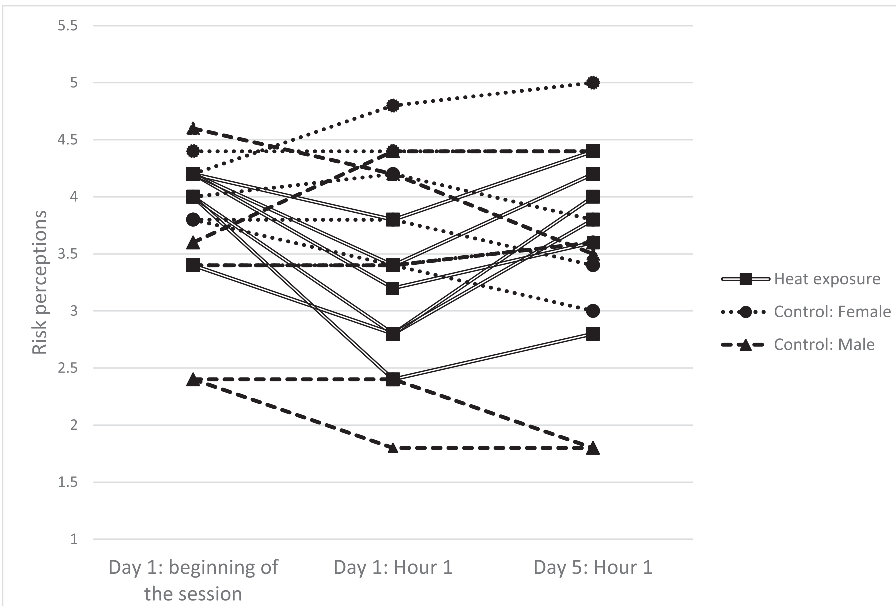

Fig. 1. Risk perceptions for health/safety-related behavioral options across times in three conditions at the individual level.

found for the experimental condition ($F_{(2,14)} = 1.01$, $p > 0.05$). A main effect was found for times of measurement ($F_{(2,28)} = 5.16$, $p = 0.012$). However, this main effect was qualified by a significant interaction between the experimental condition and times of measurement ($F_{(4,28)} = 2.86$, $p = 0.042$). This suggested that participants' risk-taking behaviors changed differently over time depending on the experimental conditions. Table 2 summarized the means and standard errors, and Fig. 2 illustrated this pattern at the individual level.

In particular, participants in the two control groups showed minimum changes across three assessment of risk perceptions (comparison of male control participants across three times: $F_{(2,8)} = 0.54$, $p > 0.05$; comparison of female control participants across three times: $F_{(2,10)} = 0.28$, $p > 0.05$). On the other hand, participants in the heat exposure group showed significant variations in their risk-taking behaviors across the three times of assessment ($F_{(2,10)} = 10.93$, $p = 0.003$). The post-hoc comparison showed that after the initial heat exposure, participants' risk-taking behaviors increased significantly compared to the baseline ($t_{(5)} = 7.20$, $p = 0.001$). In addition, participants' risk-taking also increased from baseline to post acclimatized heat exposure ($t_{(5)} = 2.99$, $p = 0.031$). Finally, there was no significant difference between risk-taking behavior from post initial exposure to post acclimatized exposure ($t_{(5)} = 0.72$, $p > 0.05$). Thus, Hypothesis 2 received support, such that heat exposure resulted in increases in participants' risk-taking behavior. Moreover, results suggested that unlike risk perceptions, acclimatization could not mitigate the effect of heat exposure on the risk-taking behavior, which addressed Research Question 2.

4. Discussion

Overall, we found that heat exposure affected individuals' risk perceptions and risk-taking behaviors. In particular, exposure to

Table 2
Means and standard errors of risk-taking behavior across times in three conditions.

	Within-subject: Timing of measure		
	Day 1: beginning of the session	Day 1: Hour 1	Day 5: Hour 1
Between-subject condition: Heat exposure			
Heat exposure	36.41 (3.50)	44.03 (3.66)	42.68 (3.72)
Control: Male	39.64 (3.83)	39.44 (4.01)	41.38 (4.07)
Control: Female	33.81 (3.50)	34.73 (3.26)	35.06 (3.72)

Note: $N = 6$ for heat exposure condition, $N = 5$ for control: male condition, $N = 6$ for control: female condition.

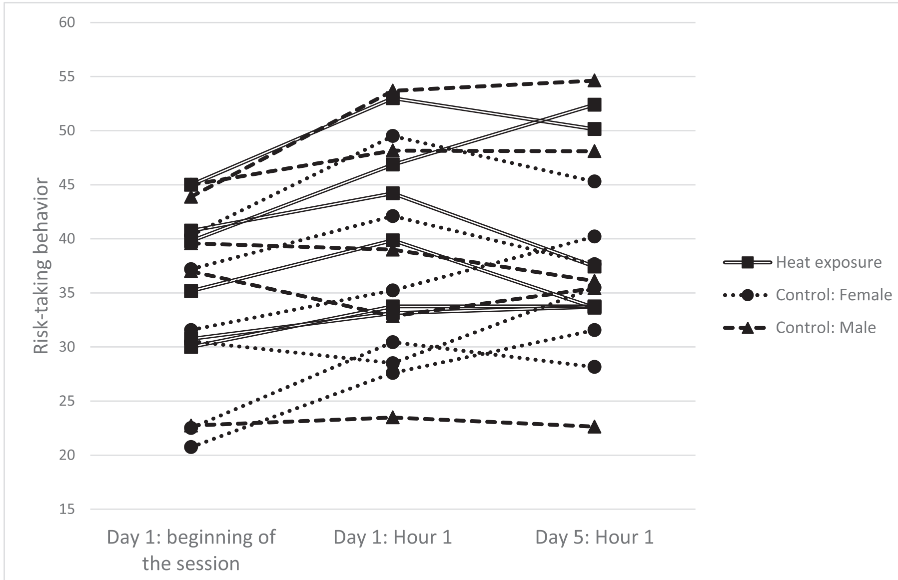

Fig. 2. Risk-taking behaviors across times in three conditions.

heat resulted in decreases in risk perceptions (i.e., considering the same activities to be less risky) and increases in risk-taking behaviors after initial exposure. However, while effects on risk perceptions were eliminated after acclimatization, participants still exhibited increased risk-taking behaviors after acclimatization. The implications of these findings will be discussed in the following sections.

4.1. Theoretical implications

Our results have important theoretical implications for understanding the effects of heat stress on increased risks for accidents and injuries. In particular, we found that for participants who were exposed to heat, their risk perceptions of the same behaviors decreased after the initial heat exposure. This suggests that when they are not used to heat exposure, heat stress may interfere with their cognitive processing, thereby changing their risk evaluations. Indeed, prior research has suggested that heat exposure may interfere with individuals' cognitive functioning, such as vigilance or monitoring (Faervik and Reinertsen, 2003) and memory-related functions such as encoding and retrieving (Curley and Hawkins, 1983). Thus, when individuals experience heat stress, they may not monitor their environment as closely, and underestimate the likelihood and severity of the potential negative consequences associated with a risky behavior. As a result, they may be more likely to take shortcuts and ignore safety procedures at work, thereby increasing their likelihood to be involved in workplace accidents or injuries.

We also found that individuals who were acclimatized to the heat exposure had similar risk perceptions of the same safety/health behaviors as their baseline. These results suggest that once acclimatized, individuals' cognitive processing of risk is less affected by heat exposure. While prior research has been equivocal on the effects of acclimatization on individuals' cognitive performance (e.g., Curley and Hawkins, 1983; Radakovic et al., 2007), our results suggest that being accustomed to the heat exposure may make individuals' cognitively-based risk assessment more resistant to the effects of changes in body temperature. It is possible that acclimatized individuals may feel more comfortable and less exhausted in the hot environment, affording them more attentional resources to carefully evaluate the perceived riskiness of various behaviors related to their health and safety.

Interestingly, we found that acclimatization did not have the similar effect on risk-taking behaviors as on risk perceptions. In particular, acclimatized participants continued to show increased risk-taking behaviors after heat exposure, rather than lowering their risk-taking behaviors back to the baseline. This suggests that cognitively-based risk assessment may not be the only mechanism explaining the effects of heat exposure on individuals' risk-taking behaviors. In particular, it is possible that exposure to heat result in highly-activated affective states (e.g., alert and energetic) in participants. These active emotional states reflect the general motivation tendency of an approach orientation, which are associated with more risk-taking as individuals tend to focus on the potential gains and downplay the possible losses (Fessler et al., 2004; Lermer et al., 2015).

Future studies should extend the current findings to further establish the external validity of the findings. For example, risk perceptions should be assessed as a mediator between heat exposure at work and employees' involvement in near-misses or accidents. In addition, indicators of attentional resources or mental exhaustion may also be examined as potential mediators to explain the effects of heat exposure on employees' risk-related assessments and risk-taking behaviors. Finally, research should explore other possible mechanisms (e.g., emotion- or motivation-based processes) through which heat exposure may affect individuals' risk-taking behaviors.

4.2. Practical implications

Our research suggests that acclimatization can be an important secondary intervention to address the risk associated with heat exposure at work. In particular, for workers who are exposed to extreme temperatures (e.g., construction workers in warm climate; foundry workers), proper acclimatization procedure, in addition to appropriate clothing, regular breaks, and proper hydration may be helpful in preventing heat-related occupational illnesses (e.g., heat stroke and heat exhaustion), as well as other accidents, injuries, and even fatalities resulting from the employees' risky behaviors (Bernard, 2002). In addition, other strategies to alter employees' risk assessment (e.g., posters to remind workers about the negative consequences associated with unsafe work behaviors) may also be helpful for reducing the effects of heat exposure on workers' risk perceptions and risk-taking behaviors.

4.3. Limitations

One limitation of our study is that it included a small sample size, which reduced the power to detect effects. Moreover, because of the human subject protection concerns, we could not randomly assign participants into the experimental versus control groups, as those in the experimental group must pass the medical prescreening to ensure that they were fit to be in the heat chamber. This limitation was addressed in two ways. First, we compared participants' sensation-seeking traits prior to the experimental sessions and found that those in the experimental versus control groups were equivalent in terms of traits that are relevant to their risk perceptions and risk-taking behaviors. This finding supported the equivalence of participants in different conditions, and partially alleviated the issue of nonrandom assignment. Thus, our results cannot be solely attributed to the inherent differences between the experimental versus control groups.

Second, our study used a mixed design, such that we compared the effects of heat exposure both between experimental versus control groups and within the experimental groups only. The within-group effect is less likely to be explained by any existing between-group differences. Thus, the internal validity of the effects associated with acclimatization may be less threatened by any preexisting between-group differences between the experimental versus control groups.

5. Conclusion

The current study examined the effects of exposure to heat on risk-related outcomes, including risk perceptions and risk-taking behaviors. We had two primary findings. First, we found that participants' heat exposure, especially prior to acclimatization, was associated with their lower risk perceptions and increased risk-taking behaviors. Second, after acclimatization, heat exposure still increased participants' risk-taking behaviors compared to the baseline. Our findings suggest that workers exposed to heat may be more accident-prone because they are more risk-taking after exposure. This effect is more pronounced when individuals are not acclimatized. Based on this, proper acclimatization may have implications for preventing occupational accidents and injuries, in addition to heat-related illnesses, for workers who are exposed to extreme heat.

References

Ahasan, R., Mohiuddin, G., Faruquee, S.M., 2002. Strenuous tasks in a hot climate-a case study. Work Study 51, 175–181. http://dx.doi.org/10.1108/00438020210430724.

Ajcardi, R., Therme, P., 2008. Sensation seeking, affective profile, and sports behavior in the prediction of risk. Int. J. Sport Psychol. 39, 356–372.

Ajzen, I., Fishbein, M., 1977. Attitude-behavior relationships: a theoretical analysis and review of empirical research. Psychol. Bull. 84, 888–918.

Anderson, C.A., 2001. Heat and violence. Curr. Dir. Psychol. Sci. 10, 33–38. http://dx.doi.org/10.1111/1467-8721.00109.

Becker-Olsen, K., Briones, R.L., 2009. Towards a drug free America: guilt processing and drug prevention. J. Res. Consumers 16, 1–6. Article available via. http://jrconsumers.com/Consumer_Articles/issue_16/Drug_Free_America_consumer2.pdf.

Bernard, T.E., 2002. Thermal stress. In: Plog, B.A., Quinlan, P.J. (Eds.), Fundamentals of Industrial Hygiene. National Safety Council, United States of America, pp. 327–355.

Center for Disease Control and Prevention, 2008. Heat-related deaths among crop workers—United States, 1992-2006. Morb. Mortal. Wkly. Rep. 57, 649–653.

Curley, M.D., Hawkins, R.N., 1983. Cognitive performance during a heat acclimatization regimen. Aviat. Space, Environ Med 54, 709–713.

DeJoy, D.M., 1999. Motivation. In: Wogalter, M.S., DeJoy, D.M., Laughery, K.R. (Eds.), Warnings and Risk Communication. Taylor & Francis, London, UK, pp. 221–244.

Faervik, H., Reinertsen, R., 2003. Effects of wearing aircrew protective clothing on physiological and cognitive responses under various ambient conditions. Ergon 46, 780–799. http://dx.doi.org/10.1080/0014013031000085644.

Fessler, D.M.T., Pillsworth, E.G., Flamson, T.J., 2004. Angry men and disgusted women: an evolutionary approach to the influence of emotions on risk taking. Org. Beh. Hum. Decis. Process. 95, 107–123. http://dx.doi.org/10.1016/j.obhdp.2004.06.006.

Fogleman, M., Fakhrzadeh, L., Bernard, T.E., 2005. The relationship between outdoor thermal conditions and acute injury in an aluminum smelter. Int. J. Indus. Ergon. 35, 47–55. http://dx.doi.org/10.1016/j.ergon.2004.08.003.

Gaoua, N., 2010. Cognitive function in hot environments: a question of methodology. Scand J. Med. Sci. Sports 20, 60–70. http://dx.doi.org/10.1111/j.1600-0838.2010.01210.x.

Garzon-Villalba, X.P., Mbah, A., Wu, Y., Hiles, M., Moore, H., Schwartz, S.W., Bernard, T.E., , 2017. Exertional heat illness and acute injury related to ambient wet bulb globe temperature. Am. J. Ind. Med. 1169–1176. http://dx.doi.org/10.1002/ajim.22650.

Gerend, M.A., Aiken, L.S., West, S.G., 2004. Personality factors in older women's perceived susceptibility to diseases of aging. J. Personal. 72, 243–270. http://dx.doi.org/10.1111/j.0022-3506.2004.00262.x.

Hancock, P.A., Ross, J.M., Szalma, J.L., 2007. A meta-analysis of performance response under thermal stressors. Hum. Factors 49, 851–877. http://dx.doi.org/10.1518/001872007X230226.

Hancock, P.A., Vasmatzidis, I., 2003. Effects of heat stress on cognitive performance: the current state of knowledge. Int. J. Hyperth. 19, 355–372. http://dx.doi.org/10.1080/0265673021000054630.

Hancock, P.A., Warm, J.S., 1989. A dynamic model of stress and sustained attention. Hum. Factors 31, 519–537. http://dx.doi.org/10.1177/001872088903100503.

Harikai, N., Takeyuki, S., Tomogane, K., Mizuno, K., Shin-ichi, T., 2004. Acute heat stress induces jumping escape behavior in mice. Physiol. Beh. 83, 373–376. http://dx.doi.org/10.1016/j.physbeh.2004.06.019.

Harris, P.R., Griffin, D.W., Murrey, S., 2008. Testing the limits of optimistic bias: event and person moderators in a multilevel framework. J Personal. Soc. Psychol. 95, 1225–1237. http://dx.doi.org/10.1037/a0013315.

Hoyle, R.H., Stephenson, M.T., Palmgreen, P., Lorch, E.P., Donohew, R.L., 2002. Reliability and validity of a brief measure of sensation seeking. Personal. Individ. Differ 32, 401–414. http://dx.doi.org/10.1016/S0191-8869(01)00032-0.

Kaptein, A.A., van Korlaar, I.M., Cameron, L.D., Vossen, C.Y., van der Meer, F.J.M., Rosendaal, F.R., 2007. Using the common-sense model to predict risk perception and disease-related worry in individuals at increased risk for venous thrombosis. Health Psychol. 26, 807–812. http://dx.doi.org/10.1037/0278-6133.26.6.807.

Lejuez, C.W., Read, J.P., Kahler, C.W., Richards, J.B., Ramsey, S.E., Stuart, G.L., Strong, D.R., Brown, R.A., 2002. Evaluation of a behavioral measure of risk taking: the balloon Analogue risk task (BART). J. Exp. Psychol. Appl. 8, 75–84. http://dx.doi.org/10.1037/1076-898X.8.2.75.

Lejuez, C.W., Aklin, W.M., Jones, H.A., Richards, J.B., Strong, D.R., Kahler, C.W., Read, J.P., 2003. The balloon Analogue risk task (BART) differentiates smokers and nonsmokers. Exp. Clin. Psychopharmacol 11, 26–33. http://dx.doi.org/10.1037/1064-1297.11.1.26.

Lermer, E., Streicher, B., Sachs, R., Raue, M., Frey, D., 2015. The effect of construal level on risk-taking. Eur. J. Soc. Psychol. 45, 99–109. http://dx.doi.org/10.1002/ejsp.2067.

Leventhal, H., Brissette, I., Leventhal, E.A., 2003. The common-sense model of self-regulation of health and illness. In: Cameron, L.D., Leventhal, H. (Eds.), The Self-regulation of Health and Illness Behavior. Routledge, London, UK, pp. 42–65.

National Institute for Occupational Safety and Health, 2016. In: Jacklitsch, B., Williams, W.J., Musolin, K., Coca, A., Kim, J.-H., Turner, N. (Eds.), NIOSH Criteria for a Recommended Standard: Occupational Exposure to Heat and Hot Environments. U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication, Cincinnati, OH, pp. 2016–2106.

Oglethorpe, J.E., Monroe, K.B., 1994. Determinants of perceived health and safety risks of selected hazardous products and activities. J. Consumer Aff. 28, 326–346. http://dx.doi.org/10.1111/j.1745-6606.1994.tb00855.x.

Radakovic, S.S., Maric, J., Surbatovik, M., Radjen, S., Stefanova, E., Stankovic, N., Filipovic, N., 2007. Effects of acclimation on cognitive performance in soldiers during exertional heat stress. Mil. Med. 172, 133–136. http://dx.doi.org/10.7205/MILMED.172.2.133.

Ramsey, J.D., Burford, C.L., Beshir, M.Y., Jensen, R.C., 1983. Effects of workplace thermal conditions on safe work behavior. J. Saf. Res. 14, 105–114. http://dx.doi.org/10.1016/0022-4375(83)90021-X.

Sarin, R.K., Weber, M., 1993. Risk-value models. Eur. J. Operations Res 70, 135–149.

Vasmatzidis, I., Schlegel, R.E., Hancock, P.A., 2002. An investigation of heat stress effects on time-sharing performance. Ergono 45, 218–239. http://dx.doi.org/10.1080/00140130210121941.

Weber, E.U., 1998. Who's afraid of a little risk? New evidence for general risk aversion. In: Shanteau, J., Mellers, B.A., Schum, D. (Eds.), Decision Research from Bayesian Approaches to Normative Systems: Reflections on the Contribution of Ward Edwards. Kluwer Academic Press, Norwell, MA, pp. 53–64.

Weber, E.U., Blais, A.R., Betz, N.E., 2002. A domain-specific risk-attitude scale: measuring risk perceptions and risk behaviors. J. Behav. Decis. Mak. 15,

263–290. http://dx.doi.org/10.1002/bdm.414.
Weber, E.U., Milliman, R., 1997. Perceived risk attitudes: relating risk perception to risky choice. Manag. Sci. 43, 122–143.
Weinstein, N.D., 1982. Unrealistic optimism about susceptibility to health problems: conclusions from a community wide sample. J Beh Med 10, 481–500. http://dx.doi.org/10.1007/BF00846146.
White, M.P., Eiser, J.R., Harris, P.R., 2004. Risk perceptions of mobile phone use while driving. Risk Anal. 24, 323–334. http://dx.doi.org/10.1111/j.0272-4332.2004.00434.x.
Yao, C., Liao, S., 2011. Measuring the antecedent effects of service cognition and internet shopping anxiety on consumer satisfaction with E-tailing service. Manag Mark. 6, 59–78. Article available via. http://www.managementmarketing.ro/pdf/articole/211.pdf.