Climate impacts in sport: Risk perception, personal experience and communication of extreme heat and climate change

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Confirmation of authorship

The candidate confirms that the work submitted is his/her own, except where work which has formed part of jointly authored publications has been included. The contribution of the candidate and the other authors to this work has been explicitly indicated below. The candidate confirms that appropriate credit has been given within the thesis where reference has been made to the work of others.

Chapters 3 and 4 are based on work from jointly authored publications. The publications are as follows:

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The candidate is the principal researcher and first author of the above cited publications.

Assertion of moral rights

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Abstract

Sports teams and athletes are already witnessing and suffering from the direct impacts of extreme heat and climate change. However, there is a relative paucity of work that includes the perspectives and experiences of the most important stakeholders – the athletes themselves. This is despite the increasing acknowledgement of the importance of personal experience of extreme weather events as a tool to influence risk perceptions related to climate change.

Using a mixed methods approach, I respond to this challenge by firstly reviewing literature on the interrelationships between personal experience of local weather anomalies, extreme weather events and climate change beliefs. Drawing on psychological theories of risk (i.e., experiential processing, heuristics, and motivated reasoning), I then conducted a series of semi-structured interviews (n=14) to explore elite athletes' perceptions, experiences, and responses to extreme heat in relation to climate change. Building on the actual heat experiences that were extracted from the interview study, I then developed a sport narrative, which was used in an online experiment (n=713) to explore its impact on risk perception and emotional responses to extreme heat and climate change compared to other message types (i.e., basic heatwave information, statistical information only, and a lay person narrative).

This thesis highlights a clear division in knowledge and awareness of the risks of heatwaves among elite athletes, relating to sport type, access to the latest research, athlete level and personal experience of impaired health and performance. A clearer sense of the urgency and risks of heatwaves and more clarity on the efficacy of coping and mitigation strategies are suggested to increase awareness, and limit illness. It also finds that amplifying athletes' personal heatwave experiences could be a promising strategy to communicate about the risks of heatwaves, with individuals reporting significantly higher heatwave risk perceptions after reading the sport narrative, relative to the control. This thesis provides a novel insight into how elite athletes conceptualise and experience heatwaves and climate change which is essential information for those tasked with communicating the risks to health and performance. It also develops and tests ways to make communication about extreme heat and climate change more effective, thus providing useful information for science communicators and areas for development for further research.

Conference presentations and non-journal publications

Conference presentations

- June 2023, Sambrook, K. *The role of sport in communicating the impacts of climate change*. Paper presented at the International Conference on Environmental Psychology. Aarhus University. Denmark.
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- May 2021, Sambrook, K**.** *Coping with extreme heatwave conditions: capturing the personal experiences among elite athletes*. Poster presented at the Leeds Doctoral Showcase Poster Competition. Online.

Practice orientated publications

Goldblatt, D., Orr, M., **Sambrook, K**., Seymour, R., and Watanabe, N. (2021). Sport 2050: Future News from a Warmer World. Available from: https://www.bbc.co.uk/sport/56972366.

Tipton, M., **Sambrook, K**., Seymour, R., Goggins, D., Forster, P., Thelwell, R., Corbett, J., Montgomery, H, and Chave, R. (2019). Hit for Six: The impact of climate change on cricket. Available from: https://basis.org.uk/resource/hit-for-six/.

Sambrook, K., & Richardson, T. (2019). Climate change means more extreme weather – here's what the UK can expect if emissions keep increasing. 06 Mar. *The Conversation.* Available from: https://theconversation.com/climate-change-means-more-extreme-weather-heres-what-the-uk-can-expect-if-emissions-keep-increasing-112745.

Goggins, D., Goldsmith, C., Grogan, C., Marsh, J., Smith-Thomas, B., Forster, P., **Sambrook, K**., Boyle, J et al. (2018). Game Changer: How climate change is impacting sports in the UK. Available from: https://static1.squarespace.com/static/58b40fe1be65940cc4889d33/t/5a85c91e9140b71180ba91e0/1518717218061/The+Climate+Coalition_Game+Changer.pdf.

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Acronyms

IPCC - Intergovernmental Panel on Climate Change

EHS - Exertional Heat stroke

EHI - Exertional Heat illness

WBGT - Wet Bulb Globe Temperature

UK - United Kingdom

US - United States

MANCOVA - Multivariate Analysis of Covariance

ANCOVA - Analyses of Covariance

ANOVA - Analyses of variance

Chapter 1: Introduction and Research Context

In this chapter, I outline the research rationale and academic justification for this work, concluding with the specific research aims and objectives, novelty and contribution of the thesis, as well as the thesis structure.

1.1 Background and context

Global surface temperature has increased by 1℃ relative to 1850-1900, which is already affecting many weather and climate extremes in every region across the globe (IPCC, 2018). While the average temperature increase may not seem significant, many land regions where people live and play sport have already warmed by >2℃ (IPCC, 2018). The Intergovernmental Panel on Climate Change (IPCC) describes recent changes across the climate system as 'unprecedented', clearly stating the link between the observed warming of the planet and human-induced climate change. Research by The World Weather Attribution group of scientists have shown that without human-caused climate change, recent heatwaves in Western Europe, India and Pakistan would have been virtually impossible (Rashid et al., 2022; Zachariah et al., 2022). Looking ahead to 2100, future predictions show that global surface temperatures will continue to rise and could be between 1℃ and 5.7℃ warmer relative to 1850-1900 (IPCC, 2023). Further warming will cause an increase in the frequency, intensity, and duration of hot extremes, defined generally as temperatures that are substantially hotter than average. At 2℃ average warming, the number of people exposed to extreme heat stress could rise from 68 million today to around one billion, resulting in tragic consequences for human health (Madge, 2021).

1.2 Heat and human health

There is scientific consensus in health research that extreme heat has profound, immediate and rapidly worsening effects on human health and will continue to jeopardise the health of future generations worldwide (Watts et al., 2021). Impacts on human health can be split into two categories: (1) direct; and (2) indirect. Directly, heat can increase the prevalence of mortality and morbidity especially among children, those with pre-existing health conditions

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Chapters 1, 2 and 6 are written in the first person singular and Chapters 3, 4 and 5 are written in the first-person plural to reflect the contribution of my supervisors.

(e.g. chronic cardiovascular and respiratory disease), athletes, the elderly and those who work outdoors (Gasparrini et al., 2017). Indirectly, rising temperatures can impact the transmission of vector borne and water borne diseases, air quality, human behaviour and vital infrastructure such as energy, transport and water (Field et al., 2014). There is increasing evidence that heat-related mortality can be attributed to a warming climate (Mitchell et al., 2016). A recent study found that climate change accounted for 37% of heat-related mortality worldwide over the period 1991-2018 (Vicedo-Cabrera et al., 2021). In 2019 alone, 1.7 million deaths worldwide were linked to extreme temperatures, with more than 356000 deaths related to heat (Burkart et al., 2021). Climate change will lead to a rise in heat-related mortality in the future (Lee & Kim, 2016; Yang et al., 2021; Huang et al., 2022). In the UK, for example, average annual deaths are expected to increase from 1400 (1990-2019) to 2500 at 1.5℃ warming and 3700 at 2℃ warming (Jenkins et al., 2022). These studies highlight the importance of heat as a global health risk factor.

1.3 Impacts of heat on sport

1.3.1 Athlete health and performance

Rising temperatures and more frequent extreme heat events (i.e., a series of unusually hot days) have potentially dangerous consequences for the health and safety of individuals participating in outdoor sport at all levels (Wald & Demorest, 2022). Heat-related illnesses are commonly viewed as existing along a continuum, moving from minor conditions such as muscle cramping to heat exhaustion, and in some cases to the life-threatening condition of exertional heatstroke (EHS) (Figure 1.1) (Leon & Kenefick, 2012; Périard et al., 2022).

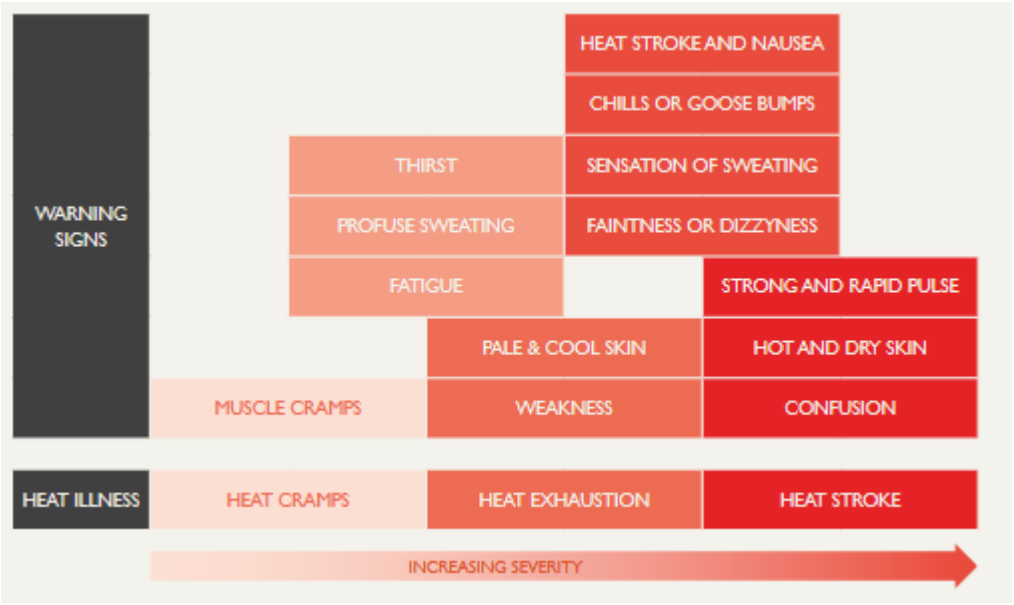

Figure 1.1: The impact of heat on athlete health and performance

Unlike regular heat illnesses, exertional heat illnesses (EHI) are related to exercise and are caused by a combination of high temperatures / relative humidity in the environment and metabolically generated body heat (Armstrong et al., 2007; Howe & Boden, 2007; Navarro et al., 2017). When the air temperature starts to increase higher than the skin temperature (normally about 33-35°C), individuals start to gain heat rather than lose it. In high humidity environments, sweat no longer evaporates from the skin and therefore will no longer provide a cooling effect, and instead will be heavily dehydrating to the individual (Tipton et al., 2019). Increases in body temperature adversely affect the physical functioning of the body and the ability to concentrate (through reduced comfort, change in mood-state and increased fatigue for example), often resulting in impaired performance when focus and attention are required. EHI are not confined to outdoor sports but can also be prominent in indoor sports where the facilities used for training and competitions are inadequately air-conditioned and are prone to over-heating (Schneider & Mücke, 2021).

Although most documented deaths from heatstroke are among vulnerable members of society (e.g., younger children and older adults), EHS has also been observed in competitive sport settings amongst elite athletes. For example, in a retrospective study examining long distance races in Tel Aviv from 2007 to 2013, 21 serious cases of heatstroke were reported including 2 that were fatal and 12 that were life threatening (Yankelson et al., 2014). Similarly, heat-related illnesses (environmental and exercise-induced) were the top three most common conditions among athletes competing in World Athletics Championships Berlin 2009 and

Daegu 2011, occurring most frequently in the race-walking events (Alonso et al., 2010, 2012). More recently, in 2018, six tennis athletes were forced to retire from the United States Open due to heat stress and exhaustion, while French tennis star, Alize Cornet collapsed at the Australian Open as temperatures soared to 42°C. In the same year, triathlete Jonny Brownlee suffered severe heat exhaustion during the Mexican Commonwealth Games and was helped over the finish line by his brother, Alistair. The following year, medical staff were on call at the 2019 World Championships in Doha after 28 athletes failed to finish the women's marathon due to the oppressive conditions. Many athletes suffered a similar fate at the Tokyo Olympics 2020, such as Spain's Paula Badosa who was forced to retire from her tennis match with heat exhaustion (Watts, 2021).

Unlike regular heatstroke, EHS can also affect young healthy individuals in peak fitness condition who would otherwise be considered as low risk (Leon & Bouchama, 2015). In the United States, EHS has been identified as one of the main causes of preventable deaths in young athletes, with numbers rising each year (Maron et al., 2009). However, individual vulnerability is highly dependent on numerous internal and external factors such as environmental conditions, individual and sport-specific factors, health status, medication and drug use and behavioural response (Leon & Bouchama, 2015; Roberts et al., 2021; Westwood et al., 2021). EHS risk is elevated in athletes who have previously experienced EHI and/or have had a recent spell of illness (Hosokawa et al., 2019; Racinais et al., 2021).

1.3.2 Sport organisations

Sport organisations at all levels are being impacted by extreme heat already. From international and national sports bodies (e.g., World Athletics, Fédération Internationale de Football Association, and the International Olympic Committee) to grass roots clubs and organisations, all are faced with the consequences of climate change. Each organisation will be forced to take action to ensure the health and safety of athletes, spectators, officials, staff and volunteers and to guarantee the future of sport as we know it (Schneider & Mücke, 2021). The potential consequences of climate change for these sports organisations include revenue loss (Kay & Vamplew, 2006), damage to facilities (Dingle & Mallen, 2020), event delays and cancellations (Rutty et al., 2015; Murfree & Moorman, 2021) and lowered participation in sport (Bernard et al., 2021). Recent examples of the consequences mentioned above include the cancellation of the Manitoba Marathon in 2022 due to extreme heat and the rescheduled events (i.e., tennis matches) at the Tokyo 2020 summer Olympics (hosted in

2021) due to the hot and humid conditions. The level of environmental heat stress experienced by organisations, teams, athletes, and staff will continue to rise in the coming years due to a combination of the increased prevalence, intensity, and duration of bouts of extremely hot weather (i.e., heat waves) that are occurring due to climate change and sport globalisation leading to more competitions being organised in extremely hot climates (Yankelson et al., 2014; Casa & Stearns, 2016; Racinais et al., 2023). Therefore, it is imperative for sport managers to assess the vulnerability of their organisation to extreme heat and climate change and consequently gain knowledge on how to adapt to the potential impacts.

1.4 Research on sport and climate

The relationship between sport and the natural environment is considered to be bi-directional. This proposes that through the emission of greenhouse gases from participation, travel and facility operations for example, sport impacts the natural environment in which it operates. But at the same time the natural environment impacts the ability of sport to operate; a concept recently dubbed 'sport ecology' (McCullough et al., 2020). However, research on sport and climate is limited and is predominantly focussed on one side of the relationship, i.e., the impacts of sport on the environment. Examples are largely in the context of the environmental impact of sport (Collins et al., 2007, 2012; Wicker, 2018), sport sustainability (Kellison & Hong, 2015; Sartore-Baldwin & McCullough, 2018) and fan engagement in environmental practices (McCullough & Cunningham, 2011; Casper et al., 2017).

While several researchers have emphasised the devastating consequences of climate change on sport and physical activity (Bernard et al., 2021), empirical research examining the impacts of climate change on sport remains scarce (Orr et al., 2022). The lack of research on the potential impacts of climate change on sport is surprising given its cultural and economic importance worldwide, along with the particular vulnerability of certain sports to environmental change, for example snow sports and golf courses (Orr and Inoue, 2018). There are, however, a few exceptions which have focussed on: (1) heat impacts on athlete and spectator health (e.g. Matzarakis & Fröhlich, 2015; Sofotasiou et al., 2015); (2) heat impacts on athlete performance (e.g. Mohr et al., 2012; Taylor & Rollo, 2014); (3) adaptive measures taken in sport; (4) climate change risk in the ski industry (Rutty et al., 2017; Scott et al., 2019) and the Olympic Games (Scott et al., 2019; Ross & Orr, 2021; Scott et al., 2022); and (5) climate vulnerability of specific sports, facilities and organizations (Dingle &

Stewart, 2018; Orr & Inoue, 2018; Dingle & Mallen, 2020; Orr, 2020;). The aforementioned research will be discussed in more detail below.

1.4.1 Impacts of heat on athlete and spectator health

Given the increasing frequency and intensity of extreme heat worldwide, many researchers have focussed on the risks of heat among athletes and spectators at major events such as the Tokyo 2020 summer Olympics and the FIFA World Cup in hosted in Qatar (Matzarakis & Fröhlich, 2015; Sofotasiou et al., 2015; Kakamu et al., 2017; Honjo et al., 2018; Gerrett et al., 2019; Vanos et al., 2019). Of primary concern was the high prevalence rate of EHI during endurance events such as race walk or marathon competitions (Honjo et al., 2018; Vanos et al., 2019), which is usually connected to the environmental conditions (i.e., high temperature and relative humidity) that athletes are subject to (Armstrong et al., 2007; Hosokawa et al., 2018). This was the case for the Tokyo 2020 summer Olympics, where concerns over the extreme heat and humidity forced organisers to relocate the race walk and marathon events to Sapporo (~800km north of Tokyo), which was predicted to experience much cooler conditions. However, despite putting this mitigation strategy in place, Sapporo recorded temperatures exceeding 30°C during each event. Consequently, forty-eight athletes were admitted to the medical station showing symptoms of EHI, with two diagnosed with EHS and three with heat exhaustion (Sugawara et al., 2022).

Beyond major events and elite athletes, researchers have also raised concerns about EHI in: (1) specific sports such as football (Yeargin et al., 2021), cycling (Australian Conservation Foundation, 2020), tennis (Smith et al., 2018), cricket (Tipton et al., 2019), baseball (Orr, 2020) and American football (Cooper et al., 2016); and (2) among young / amateur athletes (Bergeron, 2009, 2015). For example, Gilchrist et al (2011) analysed the prevalence and features of non-fatal heat illness from sports and recreation in the U.S from 2001-2009. Their results demonstrated that an estimated 5,946 people were treated each year for heat illnesses they contracted while taking part in sports or leisure activities, with the majority associated with football. The findings emphasised the importance of distributing heat illness prevention information to all physically active people, especially to those who engage in unstructured sports and leisure activities.

1.4.2 Heat impacts on athletic performance

Performance impairment due to heat has also been a key focus of research, especially in football (Mohr et al., 2012; Taylor & Rollo, 2014; Watanabe et al., 2017; Tobías et al., 2019). Watanabe et al (2017) found that at the FIFA Men's World Cup in 2014, a combination of high temperatures and humidity impaired running performance, causing a marked reduction in total distance run and distance run at high intensity. Similarly, Tobías et al (2019) found that an increase in temperature negatively impacted football player performance at major tournaments, highlighting the spike of penalty shoot-outs at the round of 16. There are also numerous studies on the effects of heat on the performances of endurance athletes. Guy et al. (2014) compared the performance of elite athletes who competed in the World Athletics Championships in hot environments (>25°C) versus colder, temperate environments (25°C) between 1999 and 2011. Their findings showed that in the heat-related endurance events, athletes' performances dropped by 3%. Previous studies have also demonstrated that increased air temperature as well as poor air quality can be associated with slower marathon times (Vihma, 2010; Helou et al., 2012). In their examination of the impact of environmental factors on half marathon performances, Hodgson et al. (2022) found that elevated temperatures and ozone concentrations all significantly harmed amateur half marathon results. The slower individuals' performance was assumed to have decreased more because of their prolonged exposure to the environmental factors.

Beyond football and endurance races, similar concerns have been raised in cricket. Tipton et al (2019) highlighted the psychological impacts of heat such as reduced concentration levels, which in turn affects the ability of players to maintain focus and make decisions. These concerns were mentioned alongside recommendations for sporting leagues to regularly update heat policies to protect the health and well-being of athletes and spectators whilst also sustaining participation, quality of competition and the attractiveness of the sport.

1.4.3 Adaptive measures taken in sport

Heat policies and guidelines are a common adaptive measure adopted by many national and international sport organisations (e.g., World Athletics, Cricket Australia, United States and Australian tennis Open, Wimbledon etc.) to cope with and prevent the potential heat-related illness among athletes and spectators. Adopting these measures allows organisations to respond quickly and efficiently to the impacts of hot and humid environments, and thus protect the health and well-being of all participants. Rather than simply measuring air

temperature, the most common approach to assess the level of heat stress in a sport setting is the Wet Bulb Globe Temperature (WBGT) (Roberts et al., 2021). The WBGT comprehensively takes into account several factors (temperature, humidity, wind speed, solar radiation, and cloud cover) that contribute to heat-related illness and as an index can provide sport organisations with specific thresholds to employ preventative measures. These measures typically include reduced play duration, extra water breaks, alteration to equipment (e.g., the removal of layers that inhibit sweating; Racinais et al., 2023) and access to cooling agents (e.g., ice towels, mist showers; Kakumu et al., 2017).

Alterations to infrastructure and equipment are also frequently used adaptive strategies to help sport organisations cope with the consequences of heat (Sofotasiou et al., 2015; Vanos et al., 2019; Kellison and Orr, 2020; Orr, 2020). Specific changes include providing shade for spectators along a marathon route (Vanos et al., 2019), to the inclusion of cooling technologies in stadiums, training sites and fan zones (Sofotasiou et al., 2015). Given the significant current and future dangers presented by extreme heat, many national and international sport governing bodies (e.g., IAAF), have begun to adapt to a changing climate and have recently published heat policies and guidelines on how to prevent heat-related illnesses. However, the parameters, environmental thresholds and key interventions employed differ significantly and thus are not always translatable or effective (Chalmers et al., 2020). For example - despite the implementation of The Extreme Heat Policy during the U.S. Open in 2018 (Jurejko, 2018) - over six tennis athletes were forced to retire due to heat-related illnesses (e.g., heat cramps, exhaustion, and stroke).

1.5 Using sport as a vehicle to communicate climate change

Sport is uniquely placed to impact individuals, communities, and whole economies through its major events. While the sector cannot tackle climate change alone, it has a hugely important role to play, both at elite and grassroots level. This is not just through the huge potential for reducing greenhouse gas emissions, but through the unique ability of sport being able to communicate, inform and inspire millions of people including business leaders, decision makers and the general public. Sport has numerous resources that are critical for raising awareness and motivating action on climate change, including: (1) broadcasting channels; (2) social media; (3) athletes as leaders; (4) promoting sustainable actions at events and at club grounds; (5) association / federation networks; (6) sport clubs' memberships and

team fans; (7) sponsors and partners; and (8) iconic venues. However, pooling these resources to fight climate change presents a challenge for sport.

1.5.1 Athlete activism and the importance of the athlete voice

Additionally, and perhaps most significantly, sport has a long history of acting as a platform for social change (Kaufman & Wolff, 2010; Coombs et al., 2020), particularly when it comes to topics that are highly politicised (Schmidt et al., 2019). For example, the 1973 tennis game between Billie Jean King and Bobby Riggs coined ‘Battle of the sexes’ was a pivotal moment for gender equality and ultimately the public’s acceptance of women’s tennis (Ware, 2011). More recently, to support the "Black Lives Matter" movement and spread awareness of racial injustice and inequality, numerous athletes and sports teams continue to take the knee (Evans et al., 2021). Athletes are increasingly leveraging their platforms to raise awareness of social issues. Marcus Rashford of Manchester United started a programme to give food coupons to the most vulnerable children in 2019. The UK government responded and approved the programme in under two days. In the midst of a worldwide pandemic, 1.3 million children received food that they might not have otherwise had access to. The efforts are an excellent illustration of how an athlete may use the influence and power provided by their platform to effect change. In each example above, sport was used as a forum to encourage the public to participate in meaningful discussions on social values, especially among those who otherwise would not have shown any interest or engagement.

Similar to issues related to social change, education alone is rarely sufficient to truly change entrenched attitudes of human apathy towards the environment (Maltarich, 2020). Further, without an emotional connection to nature, individuals rarely feel compelled to act. Outdoor athletes are likely to have this emotional connection and thus recognise the intrinsic value of the environment (Lawrence, 2022). With the rise of social media, athletes have benefitted from increased levels of social influence and some hold great power over fans especially when those fans who identify with and aspire to be like them (Brown et al., 2022). As such, athletes are increasingly speaking out due to personal motivation / concern for the environment but also because climate change is already affecting their sports (Falt, 2006). The broader literature on climate change provides evidence that well-known public personalities such as elite athletes who adopt pro-climate behaviours and actions—such as reducing or ceasing their flights—can impact others and affect the perception of what is considered "normal" (Westlake, 2017). This suggests that athletes have the potential to

exemplify and normalize the individual lifestyle changes that are required for an effective climate change response, potentially increasing feelings of collective efficacy.

Recent years have seen a rise in the amount of research on athlete activism. Athletes using their platforms to discuss or spread awareness about a topic or issue (such as racism, human rights, mental health, or environmental issues) is referred to as athlete activism, according to Haslett et al (2020). The history of activism in sport (Kilcline, 2017), media coverage of athlete activism (Schmidt, 2018), fan engagement with athlete activism (Smith & Tryce, 2019; Brown et al., 2022), and guidelines for coaches on how to support athlete activists are just a few of the areas where existing research has contributed to knowledge. According to Mihala (2019) - who studied on the participation of professional skiers and snowboarders in the fight against climate change - worry for the future of their sports and understanding of the effects of the latter substantially influenced activist behaviour.

Even though research on how the general public reacts to athlete activism has significantly increased, the research has primarily focused on how athletes use their sporting platforms to address social issues relating to race and gender (Sappington et al., 2019). Research on the public's perception of athlete involvement and their perceived authority as environmental activists has gotten much less attention, in contrast. There are a few exceptions, though. For instance, Orr (2022) employed an experimental methodology in a study located in the United States to assess the perceived credibility of five professional athletes who used social media to promote climate action. Results showed that, generally speaking, people view athletes as reasonably credible climate change communicators.

I therefore propose that sport can be used as a platform for engaging people in climate change and sustainability conversations. This is because sport is popular (Schmidt et al., 2019) and there is a high level of psychological involvement with sports teams (Kwon et al., 2005). International organisations like the International Olympic Committee (IOC) and the UNFCCC's Sport for Climate Action Framework (UNFCCC, 2018) are already supporting and promoting climate action and awareness in the sport industry. Numerous sports organisations have started taking climate action in response to these pressures and the needs of their local communities. They might do this by cutting their own emissions or by designing new facilities in accordance with guidelines like the Leadership in Energy and Environmental Design standard. Others have also made an effort to educate their fans and participants about climate challenges, encouraging others to follow in their footsteps (Inoue & Kent, 2012;

Casper et al., 2017, 2020). Recent research has shown that sports fans can respond positively to environmental initiatives and are willing to take part in the efforts to reduce the sporting events' carbon footprints, while being motivated to address their own individual carbon footprints when attending sporting events (McCullough et al., 2019). Such targeted sustainability campaigns (e.g., carbon offsets, recycling behaviours and transportation; (Trail & McCullough, 2020, 2021; Martins et al., 2022) not only educated sport participants and spectators but also encouraged change in their daily behaviours and in some cases led to people supporting sustainable policies in their local communities.

These advances offer evidence that the sport industry is moving towards a more sustainable future, and sport organisations are taking a more proactive approach to identifying and addressing climate challenges (Orr & Inoue, 2018; McCullough et al., 2020). Many sport organisations have started making contributions to the fight against climate change using their "unique" (Inoue & Kent, 2012, p. 417) status in society and their substantial platforms (Sartore-Baldwin & McCullough, 2018; McCullough et al., 2020), though the precise results of these efforts are understudied.

However, to date, little research has explored the perspectives and personal experiences of the most important stakeholders – the athletes themselves. As an exception, Scott et al (2022), integrated the opinions of top-level international snow sport competitors and coaches to help establish climatic indicators and offer new perspectives on what constitutes safe and fair competition conditions for the Olympics. However, as highlighted above, the academic discipline of sport science has primarily focused on the physiological and psychological effects of heat on health and athlete performance. They have done so through the lenses of health and performance implications (Tobias et al., 2012; Gerrett et al., 2019) and the effectiveness of specific adaptation and mitigation strategies to help athletes, spectators and sport organisations manage the impacts of heat (Alhadad et al., 2019; Kellison & Orr, 2020; Periard et al., 2021). Thus, leaving out the subjective experiences of athletes, which could be a powerful way to connect a global audience to the climate crisis.

1.6 Perception of risk

The importance of personal experience as a precursor to addressing risk has been acknowledged by research on the psychology of risk perception. According to psychological theories of risk, people's risk perceptions are significantly shaped by mental shortcuts,

environmental cues, emotions, social experiences, and contextual factors (Slovic et al., 2004; Brügger et al., 2021). For this reason, I will draw on the psychological literature to develop an overarching theoretical framework for understanding how perceptions of climate change and extreme weather are shaped.

The psychological study of judgment and decision making has highlighted several key mechanisms that account for existing links between personal experience/prior beliefs and climate change concern and action (see Figure 1.2). For example, people may rely on heuristics to form judgements and make decisions on climate change, which are rapid cognitive shortcuts which people employ to help them make judgements when evaluating overwhelming risks or complex issues (Joireman et al., 2010). There are various aspects of climate change that make people more likely to use these mental shortcuts that often result in biases when forming judgments about climate change. First of all, very few laypeople are knowledgeable of the complex scientific processes behind climate change, making it difficult to grasp (Nisbet & Myers, 2007; Morton, 2013). Second, since greenhouse gases are invisible and the impacts of climate change can seem distant in space and time, it can be hard for people to observe the direct causes and effects of climate change (McDonald et al., 2015). Third, due to the complexity and magnitude of the issue, people may find processing the risks challenging (Moser, 2010). Therefore, it is important to include the contribution of literature on cognitive and motivational biases in the context of climate change experience.

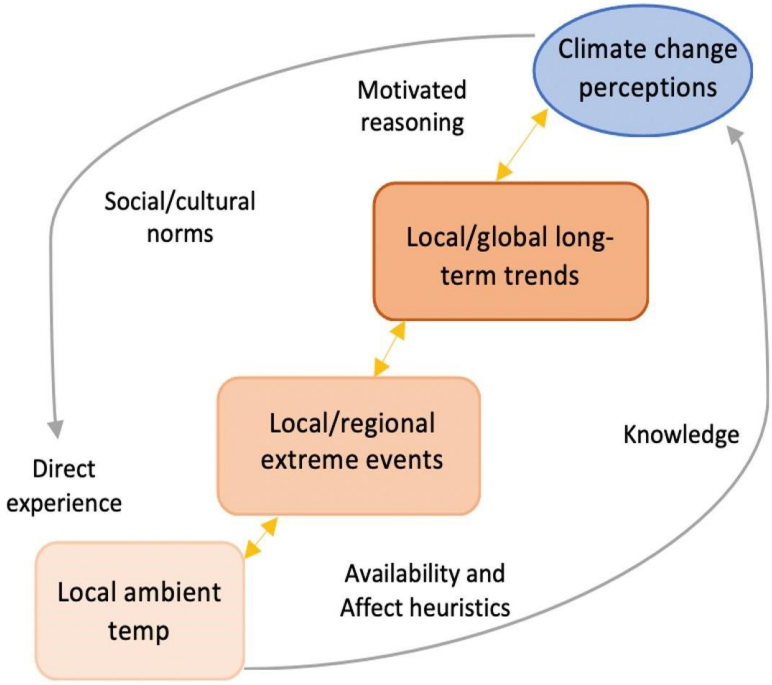

Figure 1.2: A conceptual diagram of contextual factors that relate to climate change perceptions. (Adapted from Howe et al., 2019).

1.6.1 Availability heuristic

The availability heuristic suggests that people's judgments about climate change risk are influenced by the ease with which events are recalled (Weber, 2010). Weber (2010) emphasises that when making decisions from personal experiences, individuals tend to put more emphasis on recent, more familiar events rather than temporally distant events, even when the latter could pose a greater risk. As a result, the risk of rare events (i.e., those that have a smaller probability of occurring recently) is often underweighted. When they do occur, however, they have a much larger impact on climate-related decisions than their probability of occurrence would authorize. Therefore, climate change risk perceptions based on personal experiences can be extremely unstable (Weber, 2010).

1.6.2 Affect heuristic

Another heuristic that is closely linked with personal experience and climate change risk perceptions is the affect heuristic - which implies that a person's positive or negative feelings evoked by potentially risky experiences could serve as cues to guide judgments and decisions in a complex world (Finucane et al., 2000; Slovic et al., 2004). In the context of climate change, researchers have suggested that experiences linked with negative affective responses, could increase climate change risk perceptions (Keller et al., 2006). For example, individuals

who recall feelings of discomfort and unpleasantness during a heatwave perceive the risks caused by intense heat as greater (Palutikof et al., 2004). In addition, previous studies have investigated how both the availability and affect heuristics can influence the adoption of heat protection behaviours, with results highlighting the importance of increasing the salience and negative feelings of unpleasantly hot summers (Lefevre et al., 2015; Bruine de Bruin et al., 2016). However, in the context of the UK, individuals typically feel positive about the prospect of hot summers, which tends to lower risk perceptions (Finucane, 2000; Taylor et al., 2014; Lefevre et al., 2015). Thus, personal experience with the impacts of climate change and how these experiences are represented mentally (i.e., positively, or negatively) are closely linked (Marx et al., 2007; Pachur et al., 2012) and provide equally viable explanations for the impact of past experiences. However, these concepts are yet to be studied in the context of sport.

1.6.3 Importance for research

To reiterate, the availability and affect heuristics are key mechanisms to study in the context of extreme weather as they determine how lay people judge risks (Pachur et al, 2012; Efendić et al, 2021). When forming risk judgments, people tend to rely on how easily risky events come to mind, as well as affective cues evoked by the events themselves. Brügger et al (2021) highlights a number of psychological processes that could occur when people personally experience extreme weather events such as heatwaves, which may affect the likelihood of them being noticed and remembered, and in turn influence perceptions and decision making. For example, the type / onset of an event and whether it can be seen or felt could be an important predictor of climate change risk perceptions. This idea is important for this research as it has been suggested that sudden events such as heatwaves that stimulate more senses and emotions are more likely to be noticed and remembered compared to more slow-moving, gradually accumulating disasters, which effects can be invisible (e.g., droughts; Ripberger et al., 2017; Maas et al., 2020). In addition, if an event is high in magnitude, occurs more frequently, and causes personal harm or damages the more likely such experiences are retained in memory (Howe et al., 2014). Given the potential consequences of heat on athletes' health and performance, this may explain why athletes are particularly likely to notice cues and be attentive to heat events. Social processes such as discussions with coaches, friends or family, and media coverage of the event may also deepen the level of processing (Kasperson and Kasperson, 2005). This is especially relevant to this research as sport

competitions exposed to extreme weather (especially those on an international stage) are likely to receive significant media coverage and are therefore highly likely to be in the forefront of people's minds. Thus, events that are highly publicised and emotionally charged may be perceived as more likely or significant, even if statistically improbable. Equally, this may shape public perceptions and contribute to the availability heuristic's influence. Therefore, these psychological processes linked to distinctiveness, personal relevance, and social influence are relevant to this research as they may help to explain why athletes' heat experiences are easier to recall.

1.6.4 Motivated reasoning

Climate change perceptions may also be shaped by motivated reasoning and social or cultural norms (see Figure 1.2). This idea refers to the tendency of individuals to only accept new information if it confirms their standing beliefs (i.e., confirmation bias); to interpret information closer to their prior opinions as stronger and more reliable (i.e., prior attitude effect); and to scrutinise new information that is contrary to one's beliefs (i.e., disconfirmation bias) (Druckman and McGrath, 2019). These biases affect the interpretation of new climate change information and experiences and may motivate individuals to reach their preferred conclusion on the reality of climate change regardless of accuracy or credibility (Druckman, 2015). Yet, the evidence for directional motivated reasoning in the context of climate change beliefs has recently been questioned (Druckman and McGrath, 2019). Pre-existing mental models that connect extreme weather events to climate change from past experience also increase the likelihood of noticing such events (Capstick and Pidgeon, 2014). For example, individuals may link new experiences to existing mental representations through a process of assimilation. Equally, through a process of accommodation, individuals may create new mental representations and link the experience to climate change for the first time and thus revise future expectations. If severe enough, evidence suggests that these experiences could increase risk perceptions which in turn should increase negative emotions leading to an increased motivation to seek information to process the event (Keller et al., 2006; Lujala et al., 2015; Yang et al., 2015).

The research presented above, together with the psychological processes, indicates that people's beliefs, feelings, and behaviours regarding climate change can be influenced by their personal encounters with the phenomenon. But much more must happen than just an actual

occurrence of an extreme weather event or climate-related event for one experience to change people's mental models or behaviour.

1.7 Personal experiences of impacts as a communication strategy

Elite athletes' experiences of extreme heat may be significantly different to a lay person. Firstly, the consequences for athletes can be numerous and diverse, and are often framed in a negative way and can be viewed as something to cope with rather than enjoy. As stated above, the consequences of heat exposure can range from minor problems that affect performance, such as sleep disturbance and last-minute scheduling changes, to more serious problems that worsen health and lead to heat-related stress and injuries. Therefore, given how detrimental heat events could be to health and performance, they may be more distinctive and more personally relevant to athletes, and as a result they may be especially observant and pay more attention to them compared to a spectator for example (Brügger et al., 2021). Further, it is likely that on the lead up to a sports competition (especially on the international stage), international federations, event organisers, and even the media will communicate the environmental conditions before and throughout the event (e.g. Tokyo 2020 Olympics). As a result, coaches, teams, and the athletes themselves may prepare for the expected conditions by employing specific coping and mitigation strategies. By having these regular discussions and if the media coverage is high, personal experiences would be expected to become more salient, and memorable, and as such easier to recall (Brügger et al., 2021). Therefore, it's important to capture these potentially vivid and powerful experiences as they could serve as a strong platform to speak about the risks of heat and climate change.

Despite the negative effects of heat, personal experiences are important as they could help bring the issue of climate change to the fore. Day-to-day, a lot of people feel distant from climate change and by viewing climate change in this "psychologically distant" manner decreases the likelihood of accepting the reality and severity of the issue, and thus people are less likely to adopt/support adaptive or mitigation actions (Lorenzoni & Pidgeon, 2006; Swim et al., 2009; Weber, 2006, 2010). However, previous research has shown that these personal experiences are important as they could influence climate change beliefs, attitudes, and behaviours by making climate change seem more familiar and concrete (Day, 2005; Brügger et al., 2015; Maiella et al., 2020). If it is easier to visualize what the future impacts may look and feel like, then this may motivate people to do something about it. A recent systematic

review conducted by Maiella et al (2020) echoes this sentiment and in general highlighted that individuals are more willing to adopt pro-environmental behaviours to tackle climate change when it is perceived as more proximal within the construct of psychological distance. However, the relationship between psychological distance and pro-environmental behaviours (both mitigation and adaptation) is complex and still unclear. Therefore, further research is required to investigate the potential existence of additional psychological variables related to psychological distance, mitigation, and adaptation in the context of climate change.

Previous research has studied the relationship between climate change experiences and public opinion in isolation (Whitmarsh, 2008; Spence et al., 2011; Demski et al., 2017) and has not considered how specific biases could help to explain how and why weather experiences and prior beliefs may shape individual's climate change perceptions (Brügger et al., 2021). Therefore, in Chapter 3, we first reviewed studies examining whether personal experiences shape beliefs and actions, outlining moderating factors (i.e., climate change attribution) considering relevant literature in behavioural decision research. In summary, the review highlights that there is some evidence to suggest that local weather experiences can generate climate change concern (Sambrook et al., 2021), but the capacity for personal experience to promote action may rely upon the experience first being attributed to climate change (Ogunbode et al., 2019). Attributions may be determined by prior beliefs about climate change, political ideology and/or party identification (Howe and Leiserowitz, 2013). Additionally, the empirical evidence on the interrelationships between extreme weather events (i.e., heatwaves) and climate change beliefs and actions remain mixed: while some studies support the impact of experience on beliefs and behaviours (Demski et al., 2017; Bergquist et al., 2019), others have not observed this (Ogunbode et al., 2019).

Thus, climate change perceptions may be shaped by direct local weather experiences; a process which is highly related to the availability (recency) and affect (emotion) heuristics, as well as prior knowledge on climate change. In turn, climate change perceptions – influenced by motivated reasoning, social norms, and cultural worldviews - may affect how individuals perceive local to regional weather or extreme events.

1.8 Framing climate change for effective communication

Despite an overwhelming scientific consensus that climate change is caused by humans and threatens our societies and ecosystems, many individuals still view climate change as an issue

that threatens distant populations and future generations (Leiserowitz, 2006; Lorenzoni et al., 2007). To tackle this issue and ultimately increase the salience of climate change impacts, some scholars have suggested making the impacts more personally relevant for individuals (Lorenzoni & Pidgeon, 2006; Weber, 2006; Lorenzoni et al., 2007; Spence et al., 2012). One promising strategy of effective climate change communication is the use of personal narratives (Böhm et al., 2019).

1.8.1 Importance of narratives

In this context, "narratives are a means of communicating information about something that has happened by concentrating on the causal linkages between events and usually centre on a character or characters that drive the action" (Cooper & Nisbet, 2016, p. 629). Research suggests that narratives that portray the impacts of climate change on relatable individuals can be an effective persuasive strategy (Morris et al., 2019; Gustafson et al., 2020). Since people tend to view climate change as a distant phenomenon, narratives that transform information about the consequences of climate change into more "relatable and concrete personal experiences" (van der Linden, 2015) may be particularly effective in reducing psychological distance, thereby increasing emotional engagement and personal risk perceptions (Van Boven et al., 2010; Lu & Schuldt, 2016). However, while scientists agree on the evidence for the existence of climate change and its impacts, popular narratives may range from 'scepticism and denial', with climate change often regarded as a 'hoax' to the most pressing issue of our time (Böhm et al., 2019).

Despite this, research has shown that narratives can facilitate persuasion especially among sceptical audiences (Dahlstrom, 2014). By describing a specific personal experience rather than just general facts, narratives are able to provide values and closeness to real-world objects without the need to justify the accuracy of their claims, making it difficult for audiences to generate counterarguments (Green & Brock, 2000; Green, 2006). Theoretically, narratives can aid in bridging the psychological distance that separates the audience from the problem (i.e. climate change) addressed in the message (Maiella et al., 2020). To be more precise, narratives frequently offer specific cases along with detailed character and scene descriptions (Slater & Rouner, 2002; Braddock & Dillard, 2016). These specific circumstances might serve as points of reference for individuals to begin mental simulation and reflect on their experiences (Green & Brock, 2000). Even in cases when readers do not personally interact with the characters or events shown in the narrative, this approach allows

narratives to offer contextualised information that can effectively contribute to a concrete understanding of the issue (Green & Brock, 2000; Slater & Rouner, 2002).

The engagement and immersion into the world of a narrative is termed ‘transportation’, which can be defined as “an integrative melding of attention, imagery and feelings, focussed on story events” (Green, 2006, p. 164). As such, individuals who are more immersed are more likely to align their beliefs, attitudes, intentions and behaviours with those exposed in the story (Braddock & Dillard, 2016). Similarly, the related field of exemplification theory investigates “why and under which conditions people integrate single-case information provided by the news into their personal judgments” (Brosius & Peter, 2017, p. 1). Research has shown that when statistical and narrative information are presented together in the same message, individuals perceptions tended to be more influenced by the experience of specific cases (Gibson & Zillmann, 1994). As such, the acceptance of narrative information has been termed the default outcome of exposure, unless individuals are capable and / or motivated to contest it (Green, 2006).

In the context of sport and climate change communication, the aforementioned research suggests that narratives of how climate change – specifically extreme heat – has impacted athletes may result in an audience being able to identify with those individuals and vicariously experience the impacts described (Jones & Peterson, 2017). For those readers, seeing athletes’ experience climate change impacts (i.e., vicarious experience) could act similarly to a personal experience, which could have a significant influence on individuals’ perceptions and actions on climate change (Myers et al., 2013; van der Linden, 2014).

1.9 Research objectives

In this thesis, I suggest that personal experiences of extreme weather events will be an influential factor in shaping individuals’ climate change beliefs. In the context of sport, how athletes narrate heatwave experiences, and the risks of heat and climate change will influence how individuals perceive the impacts and how relevant they are to them and society as a whole. I employ a practical application of theories in psychology and behavioural decision research to identify the personal experiences of heatwaves among a subsection of the elite athlete population and evaluate the effectiveness of a sport narrative on increasing the perceptions of the risks of extreme heat and climate change.

The objectives of this research are as follows:

1. To critically review the literature on the interrelationships between personal experience of local weather anomalies, extreme weather events and climate change beliefs.
2. To understand elite athletes' perceptions, experiences, and responses to extreme heat in relation to climate change and explore the use of their platforms for climate activism.
3. To examine the influence of heatwave message type on risk perception about extreme heat and climate change.

1.9.1 Novelty and contribution of the thesis

In Chapter 3, I outline how specific psychological mechanisms help to explain how and why weather experiences may (or may not) influence perceptions of climate change. Specifically, my review builds and expands upon past climate experience research – primarily from the fields of psychology and climate change (e.g., Whitmarsh, 2008; Spence et al., 2011; Demski et al., 2017) that have largely examined the conceptual relationship between climate change experiences and public opinion in isolation. Viewing the research reviewed through the lens of prominent psychological theories goes beyond previous research by assessing the moderating factors that may influence how people interpret weather-related experiences, which in turn may shape risk perceptions of climate change. Specifically, the review focuses on: (1) the availability heuristic; (2) experiential processing; and (3) directional motivated reasoning (see Druckman, 2015; Lujala et al., 2015; Konisky et al., 2016; Sisco et al., 2017; Ogunbode et al., 2019). By bringing together knowledge from behavioural decision research, the review findings make a unique theoretical contribution by indicating that the influence of personal experience on climate change beliefs and action is not straightforward. Instead, the strength of the relationship is likely to hinge on social-psychological determinants of climate change risk perceptions such as the recency and destructiveness of events, the specific nature of personal experience and the influence of prior beliefs.

The research is the first of its kind to explore the concept of personal experience within the context of extreme heat and elite level sport. There is a well-documented relationship between extreme heat events and increased heat illness among athletes, as well as impaired physical and mental performance (Miller-Rushing et al., 2012; Mountjoy et al., 2012;

Yankelson et al., 2014). However, the impacts of heat on athlete health and performance have largely been driven by quantitative research questions, and often overlook the importance, value, and relevance of qualitative approaches. Yet, the complexities of athletes' perceptions and experiences of heat are not easily quantified and therefore researchers have called for more qualitative research that complements traditional approaches (Bekker et al., 2020; Jong et al., 2023). This thesis responded to these methodological research needs by adopting a mixed methods approach to examine personal experience within the context of extreme heat and elite level sport. Thus, my research findings also make an empirical contribution by providing new insights into elite athletes' perspectives on / experiences of extreme heat, the factors affecting knowledge and understanding of the risks, as well as the enablers and barriers to communication. Specifically, the findings demonstrate that elite athletes have powerful narratives to share and have unique and important insights to offer to the climate change discourse, particularly with respect to the impacts of extreme heat events, current responses, and options for adaptation.

Chapter 4 highlights that some athletes have powerful narratives to share but many were unsure of how and if to communicate their stories. Therefore, using an online experiment, Chapter 5 builds on these findings and sought to examine to what extent a sport narrative could influence risk perceptions and emotional responses related to heatwaves and climate change. The paper makes a methodological contribution by developing four short messages (~250 words), that differed according to the type of evidence or narrative presented in a heatwave message (i.e., basic heatwave information, statistical information only, lay person narrative and sport narrative), all of which could be used as tools for future climate change communication. Although communication studies of this general type (i.e., comparing the impact of statistical information vs narrative) have been conducted in other fields, such as health and social sciences (Lowe et al., 2006; Winterbottom et al., 2012; Jones, 2014; Braddock & Dillard, 2016; Shaffer et al., 2018), to the authors' knowledge, this work presents the first of its kind to test the influence of an elite athletes' real life extreme heat experience on risk perceptions related to heatwaves and climate change. This study's findings make an empirical contribution by indicating that, the message highlighting statistical evidence was most effective in eliciting climate change risk perceptions, whereas the message highlighting an athletes' experience was most effective in eliciting heatwave risk perceptions. These findings advance our understanding of the types of evidence that could most influence risk perception in the context of heat and climate change. The latter finding

relating to athletes' experience should be considered especially important, as it adds a key piece of evidence to work relating to the credibility of athletes as messengers of environmental issues (Orr, 2022). Despite the plethora of athletes already exposed to the impacts of heat, this work shows how these negative experiences could potentially be used to make a positive contribution to heat risk communication efforts. Highlighting the potential of elite athletes to communicate the effects of extreme heat is particularly timely and essential, given the recent discussions taking place with regards to the potential of the sporting world to be a powerful force to inspire and accelerate climate action.

1.10 Thesis structure

This thesis is divided into six chapters. The introduction (Chapter 1) has developed a research rationale by delving into the wider literature on the impacts of heat on athletes, how sport interacts with the environment and vice versa and provides justification for using sport as a vehicle to communicate the risks of climate change. This section also outlines knowledge gaps and how they are addressed within the thesis before introducing psychological theories of risk and the rationale for studying personal experience in a sport context. Chapter 2 then describes the aims and objectives of the thesis, before providing details of the research design and overarching methodological approach, as well as the theoretical and analytical underpinnings.

The three chapters that precede the methodology include the published work of this doctorate and are referred to as papers one, two and three. The first two have been published, while the third is fully developed and formatted and is close to being ready for submission.

Paper one (Chapter 3) reviews studies that look at how personal experiences of local weather anomalies and / or extreme weather can affect climate change beliefs and behaviours, detailing moderating factors (such as climate change attribution) and taking into account pertinent behavioural decision research. For the first time, this paper considers how certain cognitive and motivational biases such as the availability heuristic and motivational reasoning could aid in the explanation of how and why weather experiences and prior beliefs may influence people's perceptions of climate change. In doing so, this paper provides a solid understanding of the links between personal experience, prior beliefs, concern and action about climate change as well as the mechanisms underpinning the associations.

Paper two (Chapter 4) develops the theoretical and practical contribution of this thesis by gaining an in-depth understanding of elite athletes' experience of heatwaves and climate change and studying the importance of personal experience in a sport context. It should be noted here that this paper was motivated by the gaps identified in previous research in sport science / sport management and by theories in psychology and behavioural decision research which aim to account for the links between personal experience and climate change risk perceptions identified in Chapter 3. Spanning the period August 2020 to June 2021, the paper applies semi-structured interviews to understand elite athletes' perceptions, personal experiences and responses to extreme heat in relation to climate change as well as exploring the use of their platforms for climate activism. The primary focus of this paper is to explore how elite athletes conceptualise and experience heatwaves and climate change. By introducing the subjective heat experiences of elite athletes for the first time, this paper demonstrates that elite athletes are frequently unaware of the causes, effects, and necessity of addressing heatwaves and climate change. Despite the uncertainties, it is highlighted that athletes are usually aware of the continuous struggle that heatwaves and climate change pose for sport and future generations, with worries that further warming will have a severe impact on grassroots sport, participation, and human health. As such, the majority of athletes are motivated to use their platforms to discuss the issue of climate change and identified a variety of enablers (such as environmental awareness) and barriers (such as lack of knowledge and education) that affected their ability to communicate climate change issues to a variety of different audiences.

The third paper (Chapter 5) examines empirical data collected as part of a pre-test, post-test online experiment in order to assess how a sport narrative might affect how people perceive risk and how they feel about extreme heat and climate change compared to other message types (such as basic heatwave information, statistical information only, and a layperson narrative). It presents statistical analyses on heatwave and climate change risk perceptions and emotional responses (positive and negative) with message type as between subject factors. Participant's pre-test scores were used as the covariate in the analysis. The main findings indicate that relative to the control, individual's climate change risk perceptions were significantly higher in the statistical group, whereas individual's heatwave risk perceptions were significantly higher in the sport narrative group. In addition, older people and those that support the conservative party were more likely to have lower climate change risk perceptions, whereas higher education was linked to greater climate change risk

perceptions. However, no significant effects of message type on participants positive or negative emotional responses were found.

Chapter Six discusses the wider implications of the three manuscripts. It first outlines the contributions of this thesis to knowledge and practice. The discussion comes to a close by reflecting on the research design, any potential limitations that were discovered throughout the doctorate, as well as identifying several areas as priorities for future research.

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Chapter 2: Methodology

This chapter outlines the philosophical and methodological approach underpinning the research. Firstly, it justifies the methodological approach for the thesis. Secondly, this chapter summarises the data collection and analysis procedures used within each paper. Additional details on the methods used within each paper are included within the specific papers reported in Chapters 3, 4 and 5.

2.1 Research philosophy

The philosophical foundation that underpins the method and design of this thesis is derived from the critical realism paradigm. Critical realism recognises that there is a 'real world' that can be observed objectively – while at the same time assumes that our knowledge about the real world is "historically, socially and culturally situated" (Archer et al., 2016 p.6). In essence, realists contend that reality is made up of multiple layers containing structures and mechanisms that can be both observed and experienced. For example, patterns of behaviour can be directly measured in an experimental setting to examine relationships between different variables; a method that is commonly used by quantitative researchers. At the same time, researchers may want to observe this behaviour in a real-world context to explore how causal mechanisms interact with one another; an approach which is commonly associated with qualitative research (Roberts, 2014). Thus, critical realism aligns well with a mixed methods research design as it allows researchers to use all available methods to fully explore and understand the structures and mechanisms of what can be observed and experienced, rather than limiting or constraining researcher's choices (Venkatesh et al., 2013). In doing so, critical realism allows for multiple ways of producing knowledge about the same observed phenomenon and builds on the premise of seeking an explanation rather than the empirical truth (Thompson et al., 2010).

This thesis therefore assumes that although there is a single ontological reality with objective events and processes, each person's experience and interpretation of that reality is unique and personal to them. The research approach and methods used in this thesis are therefore guided by a critical realist perspective, combining quantitative techniques where proven scientific knowledge already exists with more exploratory qualitative techniques when there is little to no pre-existing knowledge about the research topic. For instance, athlete perceptions and

personal experience of heatwaves have largely been overlooked in the existing literature, justifying the choice of a mixed methods approach when exploring this aspect of the thesis.

2.2 Rationale for a mixed methods approach

Based on the research philosophy of critical realism, this thesis adopts a mixed methods design which consists of three phases of data collection and analysis. Previous studies have sought to provide various definitions of a mixed methods approach (Johnson et al., 2007) but this thesis utilises the definition provided by Driessnack et al (2007):

> "Multiple methods, or multi-method design, is when two or more research projects are conducted, each complete in itself, to address research questions and/or hypotheses, a topic, or a program. As with mixed methods, the studies may be a combination of quantitative methods, qualitative methods, or both. The projects can be implemented concurrently or sequentially" (Driessnack et al., 2007, p. 1047).

A mixed methods approach requires researchers to collect and analyse both quantitative and qualitative data for a single study (Bowers et al., 2013; Shorten & Smith, 2017). By capitalizing on the strengths of both types of data, researchers are able to explore a range of perspectives and uncover relationships that exist between complex layers of multifaceted research questions (Shorten & Smith, 2017). In doing so, mixed methods research generates more robust results and can address extensive research questions. This type of research can also compensate for weaknesses of single research methods, tells a more thorough, detailed and convincing story, which provides a holistic understanding of phenomena (Davis et al., 2011).

Considering the above, this thesis integrated both quantitative and qualitative methods to address the overarching aim. Each phase is associated with one of three research objectives described above and employs different data collection and analysis techniques. Table 2.1 gives an overview of each research objective, research questions as well as data collection and analysis methods. Specifically, this thesis used an exploratory sequential design first collecting qualitative interview data to inform the design of the online experiment and equally using the quantitative research to expand and enhance the qualitative findings (Creswell & Clark., 2017). As such, one method feeds into another using findings from both methods to learn something more about how heat experiences in sport could be used as a tool

for risk communication. The design is based on the premise that an exploration is needed primarily for the development of materials that are not available in the literature.

The research began with and prioritized the collection and analysis of qualitative interview data in the first phase. Building on the exploratory results, I conducted a second, quantitative phase to test the materials developed in the qualitative phase. For example, I collected qualitative stories about elite athletes' experiences of extreme heat and analysed the stories to identify the specific conditions, contexts, consequences, and responses to training and competing in extreme heat. Considering the results, I developed a narrative by combining the elite athletes' stories and used it to assess the overall effect of this type of information on people's heat and climate change risk perceptions. A more detailed description of the data collection and analysis methods used to address each research objective is explained in the individual chapters.

An overview of the three research objectives and three studies, as well as research questions and methods can be seen below in Table 2.1.

Table 2.1: Summary of research objectives and studies undertaken.

Research objective 1: **To critically review the literature on the interrelationships between personal experience of local weather anomalies, extreme weather events and climate change beliefs.**	
Study 1	Chapter 3: The Role of Personal Experience and Prior Beliefs in Shaping Climate Change Perceptions: A Narrative Review
Research questions	1. Do personal experiences shape climate change beliefs and action? 2. What factors moderate the impact of personal experience on climate change beliefs and action? 3. Do Prior Beliefs Shape an Individual's Perception of Climate Change Impacts?
Method	Narrative review (n = 42)

Research objective 2: **To understand elite athletes' perceptions, experiences, and responses to extreme heat in relation to climate change and explore the use of their platforms for climate activism.**	
Study 2	Chapter 4: Outdoor sport in Extreme heat: Capturing the personal experiences of elite athletes
Research questions	1. What is the current knowledge and awareness of the causes and risks of heatwaves among elite athletes? 2. How has extreme heat affected athlete health and performance? 3. How do athletes and organisers prepare and respond to heat waves?

	4. Why do elite athletes choose to engage in climate activism or choose not to?
Method and analysis	Semi-structured interviews (n = 14) Thematic analysis

Research objective 3: **To examine the influence of heatwave message type on risk perception about extreme heat and climate change.**	
Study 3	Chapter 5: The role of sport in communicating the impacts of climate change
Research questions	1. To what extent do different heatwave evidence types affect climate change risk perceptions, heatwave risk perceptions and emotional responses? 2. What is the effect of evidence type on behavioural response? 3. What is the effect of evidence type on perceived informativeness?
Method and analysis	Online experiment (n = 713) Multivariate analysis of covariance (MANCOVA)

2.3 Data collection

As highlighted in Table 2.1, to meet objective 1, I conducted a narrative review to assess the interrelationships between personal experiences of local weather anomalies, extreme weather events and climate change beliefs. This is reported in Chapter 3. The empirical evidence associated with the subject area is relatively new (dates back to ~2008) and therefore I decided to undertake a narrative (rather than systematic) review to obtain a broad perspective on the topic. Comprehensive searches for relevant studies were performed but they did not follow a specified protocol or strategy. Narrative reviews can help the researcher identify patterns, gaps or inconsistencies in the body of knowledge and are therefore well placed to gain a deeper understanding of the topic, as well as ideas for future research (Paré and Kitsiou, 2015).

Secondly, to meet Objective 2, I conducted semi-structured interviews with elite athletes. This is reported in Chapter 4. Participants were recruited through snowball sampling, which allowed approaching elite athletes who may otherwise be hard to reach (Waters, 2015). I initially started sharing the call for participants using my established sport network to establish initial links, with sampling momentum developing from these, capturing a small pool of participants. The agreeable participants were then asked to recommend other contacts who may fit the research criteria and who might also be willing to take part. They were then asked to recommend other potential participants, and so on (Parker et al., 2019).

Semi-structured interviews are a useful research tool for exploring in-depth experiences, which may be sensitive, such as the effects of competing in the heat. Due to its open-ended nature and emphasis on responding to the unexpected, this approach offered a balance of structure and flexibility. All of the interviews took place online (via Microsoft Teams or Zoom), lasting from 30 minutes up to 1 hour. The interviews began with questions about heatwaves, such as "could you tell me what heatwaves mean to you?" The topic of climate change, unless brought up by the participant, was explored at the end of the interview, in order to see whether participants were engaged with the issue. Each interview was audio-recorded and transcribed. Notes were also taken directly after the interview. In total, 14 interviews were carried out with nine males and five females, aged between 20 and 41 years (M = 28.7 years) and most had a university degree. This outcome was partly determined by thematic saturation, meaning that data collection was ended when few new perspectives, insights and themes were retrieved by further interviews (Saunders et al., 2018), and because of the time constraints of the project.

To meet Objective 3, I conducted an online experiment to explore how a sport narrative could impact risk perception and emotional responses to extreme heat and climate change compared to other message types (i.e., basic heatwave information, statistical information only and a lay person narrative). This is reported in Chapter 5. In order to measure the effect of different messages on risk perceptions, I employed a pretest-posttest design, which is a design widely used in behavioural research, principally in order to compare groups and gauge the influence of experimental conditions (Dimitrov & Rumrill, 2003). Participants in the pre-test study completed an online survey with 6 sections (e.g., risk perception related to climate change, risk perception related to heatwaves, emotional response, sport fandom, numeracy, and socio-demographics) after giving their informed consent. To prevent order effects, the survey's sections were randomized. The same subjects were asked to complete the post-test study a week later. One of five message types were presented to participants at random: basic heatwave information, statistical information only, layperson narrative, sport narrative, and control (i.e., no information). Following the brief message, participants were asked the same survey questions as in the pre-test research, plus additional ones about how informative they thought the message was and their immediate behavioural response.

The interview data collected in the previous phase, informed the development of the sport narrative, which described the personal heatwave experience of an elite marathon runner

called Sam from the UK, who competed in the Tokyo 2020 Olympics. A total of 713 participants completed the study. Participants were randomly assigned to one of five message groups – basic heatwave information (N = 144), statistical information only (N = 144), lay person narrative (N = 142), sport narrative (N = 146) and control respectively (i.e., no information; N = 137).

2.4 Data analysis

I performed all statistical analyses in SPSS Statistics 26 and processed the qualitative data through thematic analysis using NVivo 12 (QSR International). Themes in the data were organised using thematic analysis (Braun & Clarke, 2006). Because thematic analysis is a flexible method, it allowed me to analyse the data in a variety of ways, including inductively (e.g., focused on new experiences) and deductively (e.g., guided by previous literature). Thematic analysis is an iterative form of data analysis, and it entails going back and forth through a framework of six phases. These phases are described in more detail in Chapter 4.

To test for statistical differences between message types, I performed a multivariate analysis of covariance (MANCOVA) while controlling for pretest scores. This analysis was chosen to test the effects of message type on heatwave and climate change risk perceptions, as well as emotional responses, and to control for the Type 1 error. For analyses producing significant interactions, follow up analyses of covariance (ANCOVA) were conducted comparing heatwave and climate change risk perceptions at each message type.

2.5 Research ethics

Two components of the data collection required an ethical review. The second study involved assessing perceptions of heatwaves and associated experiences among elite athletes (ethical review reference: LTSEE-114). The main ethical concerns related to the engagement of elite athletes during in-depth interviews. In particular, some participants may have felt a level of discomfort when talking about their personal experiences with heatwaves and answering questions on this topic. To address this issue, participants were provided with details of independent support websites and helplines, in case they wished to speak further about their experiences and associated feelings. More generally, it is vital for social science researchers to clearly inform participants about the purpose of the project, to provide informed consent and to state the implications of taking part in the research. Prior to each interview, participants received information about the purpose of my research, data anonymity, data

storage, the process of sharing data with other researchers. Participants were also informed that they had the right not to answer any questions they felt uncomfortable with and could stop the interview at any time without providing a reason. Participants were informed of their rights under the Data Protection Act (2018), which includes the right to: (1) be informed about how data is being used; (2) access data; (3) update incorrect data; (4) have data erased; (5) stop the processing of data; and (6) receive and re-use data. Interviews were conducted online and therefore participants used an electronic signature platform to provide informed consent.

The third study involved an online experiment to assess how the general public perceived information about extreme heat and climate change (ethical review reference: LTSEE-122). Given the nature of the topics of the experiment it was not expected that participants would become upset or agitated during the completion of the studies. However, in some cases participants may not have felt comfortable reading about the impacts of heatwaves and climate change and thus it was stressed that participants were free to discontinue their participation at any time.

2.6 Novelty and methodological contribution

Critically, the mixed methods approach provides novel insights that would not have been collected from either purely quantitative or qualitative methods alone. In total, I used three diverse research methods to answer the research objectives, combining qualitative in-depth approaches with more robust, quantitative methods. As noted above, studies on the impacts of heat on athlete health and performance have largely been driven by quantitative research questions, and often overlook the importance, value and relevance of qualitative approaches. However, the complexities of athletes' perceptions and experiences of heat are not easily quantified and therefore researchers have called for more qualitative research that complements traditional approaches (Bekker et al., 2020; Jong et al., 2023). This thesis responded to these methodological research needs by adopting a mixed methods approach to examine personal experience within the context of extreme heat and elite level sport. For instance, I incorporated the athletes' heat experience into an online experiment to extract new insights beyond the knowledge acquired from the separate interview study (Guetterman et al., 2015).

In addition, to address the third objective I developed four messages that outlined the impacts of heat on human health. The structure of each message was identical across conditions, with each message containing information on heatwave definition, impacts and future change, but varied in the format of communication used to convey the message (e.g., statistical information only or narrative etc.). The experiment highlighted that athletes' heat experiences were most effective in increasing heat risk perceptions, while statistical evidence was shown to be most effective in increasing risk perceptions about climate change. This allowed me to identify and develop new ideas for heat risk communication. The findings reported here suggest that athletes speaking authentically about their experience and what heat means to them and their sport could be an effective approach to heighten risk perceptions. This finding is important and particularly timely as heatwaves are projected to become more frequent and intense in the UK, yet the public are not fully aware or sufficiently informed about the risks from heat (Howarth et al., 2019). As a result, individuals typically feel positive about the prospect of hot summers, which tends to lower risk perceptions (Finucane, 2000; Taylor et al., 2014; Lefevre et al., 2015). Therefore, more effective communication is essential to ensure better resilience to these risks and given athletes repeated exposure to heat and other climate impacts, sport is well placed to raise awareness to the consequences of such extreme weather events. This work could be replicated either for future research purposes and/or to develop more engaging information on heatwaves and climate change, and ultimately increase risk perceptions on climate change and it's impacts across communities in the UK.

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Chapter 3: The role of personal experience and prior beliefs in shaping climate change perceptions: A narrative review

More people are exposed to more frequent and severe extreme weather events, such as intense heat waves, wildfires, floods, and severe storms, as a result of ongoing human-caused climate change. These events offer a chance for people to observe the often-intangible consequences of climate change, making the risk seem more real. However, research has shown that these variations in extreme weather have not yet consistently led to shifts in people's beliefs about climate change or their willingness to take action and may in fact be influenced by several social-psychological factors. Therefore, this chapter addresses objective 1, and critically reviews the literature on the interrelationships between personal experience of local weather anomalies, extreme weather events and climate change beliefs.

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Please note that this paper was published in U.S. English, hence the change of spelling here.

3.1 Abstract

Global climate change is increasing the frequency and intensity of extreme weather events such as heatwaves, droughts, and flooding. This is the primary way many individuals experience climate change, which has led researchers to investigate the influence of personal experience on climate change concern and action. However, existing evidence is still limited and in some cases contradictory. At the same time, behavioral decision research has highlighted the importance of pre-existing values and beliefs in shaping how individuals experience changes in environmental conditions. This is in line with theories of motivated reasoning, which suggest that people interpret and process information in a biased manner to maintain their prior beliefs. Yet, the evidence for directional motivated reasoning in the context of climate change beliefs has recently been questioned. In the current paper, we critically review the literature on the interrelationships between personal experience of local weather anomalies, extreme weather events and climate change beliefs. Overall, our review shows that there is some evidence that local warming can generate climate change concern,

but the capacity for personal experience to promote action may rely upon the experience first being attributed to climate change. Rare extreme weather events will likely have limited impact on judgments and decisions unless they have occurred recently. However, even recent events may have limited impact among individuals who hold strong pre-existing beliefs rejecting the reality of climate change. We identify limitations of existing research and suggest directions for future work.

3.2 Introduction

Climate change is a global challenge that has already had a detrimental impact on the environment and human health, leading to increases in the magnitude and frequency of extreme weather events such as heatwaves, droughts, and flooding (Seneviratne et al., 2012). Despite compelling evidence for rapid climate change and the urgency of the issue (IPCC, 2018), some individuals remain skeptical about the risk and reality of climate change (Whitmarsh, 2011). A key factor that can shape perceptions of climate change is people's personal experience of extreme weather events and/or local weather anomalies such as temperature fluctuations (i.e., deviations from the normal seasonal temperature) (Spence et al., 2011; Zaval et al., 2014; Demski et al., 2017). Such experiences provide an opportunity for individuals to witness the otherwise abstract effects of climate change and as such make the risk more tangible and familiar (Lorenzoni and Pidgeon, 2006; Weber, 2010; Spence et al., 2011; Smith and Joffe, 2013; Reser et al., 2014). Specifically, such experiences can reduce perceived psychological distance of climate change from the self on different dimensions, including temporally, socially, and geographically (McDonald et al., 2015). Furthermore, experiences with extreme weather events may also provoke negative affective responses, which can increase perceived risk (Keller et al., 2006), increase environmental concern and promote action (Demski et al., 2017; Bergquist et al., 2019).

However, personal experiences of climate change impacts may not always increase concern or motivate action. The literature on motivated reasoning suggests that people often process new information in a biased way to generate their favoured conclusion and maintain their prior beliefs (Kunda, 1990; Dawson et al., 2002; Myers et al., 2013). As such, individuals' prior beliefs about climate change may influence how they interpret fluctuations in local weather conditions. This can substantially reduce the likelihood of skeptical individuals acknowledging the reality and consequences of climate change, which in turn could lower their willingness to adopt adaption (e.g., paying for flood damage insurance) and/or

mitigation actions (e.g., deciding to travel by train rather than flying; Lorenzoni and Pidgeon, 2006; Weber, 2006).

In this mini review, we provide an overview of existing literature on the interrelationships between personal experience of local weather anomalies, extreme weather events and climate change beliefs. We first review studies examining whether personal experiences shape beliefs and actions, and outline moderating factors, considering relevant literature in behavioral decision research. Next, we review work examining the influence of pre-existing climate change beliefs on interpretations of weather-related experiences, in connection to work on motivated reasoning. Finally, we identify limitations of existing research and suggest directions for future research. An overview of the basic characteristics of all studies reviewed and main results for each study can be found in Appendix A1.

3.3 Does Personal Experience Shape Climate Change Beliefs and Action?

There is evidence to suggest that subjective (self-reported) experiences of local weather anomalies could increase belief in and concern for climate change (Krosnick et al., 2006; Howe and Leiserowitz, 2013; Zaval et al., 2014; Howe, 2018). For example, survey respondents in Australia and the United States (U.S.) who reported warmer-than-usual temperatures on the day of study expressed greater belief in and concern about climate change (Li et al., 2011). However, these studies are limited by the cross-sectional and self-reporting nature of the data and hence a causal relationship between personal experience and climate change beliefs cannot be established.

Studies that have measured the effect of observed temperature fluctuations on climate change beliefs provide evidence that abnormally warm temperatures in the short term (Joireman et al., 2010; Egan and Mullin, 2012; Hamilton and Stampone, 2013) and the long term (Deryugina, 2013; Shao et al., 2014, 2016; Shao, 2017) are important predictors of climate change beliefs and risk perceptions. For example, three 10-year studies in the U.S. reported a positive relationship between increasing summer temperatures and belief in the immediate impacts and severity of climate change (Shao et al., 2014, 2016). Other studies, however, did not find clear associations between short and long-term local temperature fluctuations and climate change concern (Li et al., 2011). Shao et al. (2016) and Deryugina (2013) argued that this may be due to differences in measurements of short-term temperature (i.e., monthly rather than daily data) and survey questions used to assess climate change beliefs.

Alternatively, Brody et al. (2008) indicated a possible misunderstanding of the risks presented by long-term temperature change on individual well-being.

A smaller number of studies have examined specifically whether experiences of extreme weather events influence perceptions of climate change. For example, early research found no differences in climate change concern between flood and non-flood victims in the United Kingdom (U.K.) (Whitmarsh, 2008), with respondents reflecting a view that flooding was a separate issue from climate change and was instead caused by local changes such as road resurfacing.

Contrasting with these initial findings, more recent studies have found that personal experience with severe storms and associated floods (Spence et al., 2011; Taylor et al., 2014; Lujala et al., 2015), hurricanes (Bergquist et al., 2019), heatwaves (Dai et al., 2015), and droughts (Carmichael and Brulle, 2017) can influence climate change beliefs and concern, at least temporarily. For example, Spence et al. (2011) found that respondents in the U.K. who reported direct flooding experience expressed a higher level of concern about climate change impacts, compared to non-flood victims. Similarly, Demski et al. (2017) documented an increase in concern about climate change, as well as heightened personal salience of climate change issues and negative emotional responses following flooding experiences. Beyond flooding experiences, Dai et al. (2015) recorded participants' experiences of several extreme weather events (e.g., heavy rainfall, heatwaves, droughts, and avalanches) in five Chinese cities and found correlations between perceived experiences (particularly heatwaves) and climate change beliefs.

There is also some evidence that personal experience of extreme weather events may motivate individuals to act on climate change (Spence et al., 2011; Broomell et al., 2017). For example, Demski et al. (2017) showed that higher levels of personal and local threat from climate change following a flooding experience can prompt actions such as changing to a green energy supplier, as well as support for climate-related policy. Similarly, a study in Vietnam illustrated that flooding experience was strongly associated with intentions to implement adaption actions (Ngo et al., 2020). Other studies, however, suggest that experience of extreme weather events is associated with perceived threat from climate change, but not with willingness to take action (Whitmarsh, 2008; Brulle et al., 2012; Carlton et al., 2016). For example, a recent survey found that self-reported flooding experiences

significantly predicted perceived threat from climate change but did not influence mitigation intentions (Ogunbode et al., 2019).

3.3.1 Factors Moderating the Impact of Personal Experience on Climate Change Beliefs and Action

Overall, the empirical evidence on the relationship between personal experience of extreme weather events and climate change concern and action remains mixed. The contrasting findings may partly reflect that these experiences only generate climate change concern and action under particular circumstances that can affect memory strength for events and their impact on decisions, namely when events are: (1) relatively recent (Konisky et al., 2016); (2) linked with significant personal and/or financial damages (Lujala et al., 2015; Sisco et al., 2017; Brügger et al., 2021); (3) experienced as abnormalities in temperature (Sisco et al., 2017); and (4) attributed to climate change (Ogunbode et al., 2019). We discuss these moderating factors in more detail below.

Firstly, more recent extreme weather events may have a significant impact on climate change concern and action, due to the ease with which they are recalled (Keller et al., 2006). In recent years, research on risky choice has investigated how personal experience affects judgment and decision making under risk. One aspect of this line of research has focused on rare (and extreme) events; this is particularly relevant in the context of climate change as most (extreme) weather events (e.g., heatwaves, flooding) have a small probability of occurrence. When making decisions based on experience such rare events are generally underweighted (i.e., their impact on making choices/taking action is smaller than their objective probability suggests). This is because their probability of having recently occurred is (on average) small. However, when they occur, their impact on future decisions can be larger than what is warranted by their objective probability, suggesting strong sequential dependencies and recency effects (Hertwig et al., 2004; Weber, 2010). This implies that personal experience of extreme (and rare) weather events can cause unstable effects on climate change beliefs, and that the specific nature of personal experience is a key determinant. For example, recency effects can be amplified if the event was linked with personal and financial damage (Sisco et al., 2017). Similarly, a study in Norway showed that respondents who had suffered damage from a climate-related event such as flooding or a landslide were 40% more likely to be concerned about climate change (Lujala et al., 2015). However, as it has already been mentioned [see Ogunbode et al. (2019)], experiencing

extreme weather events may not necessarily lead to taking action, while at the same time may increase concern about climate change. This is similar to what Barron and Yechiam (2009) observed in a sequential risky choice task: while people's choices showed reduced sensitivity to rare events (i.e., underweighting), their probability judgments/estimations suggested overestimating the occurrence of such events. Recent research has attempted to unpack aspects of this paradoxical finding, for example whether people's choices and judgments are susceptible to biases arising from misinterpreting sequential patterns (similar to gambler's fallacy; Plonsky et al., 2015; Szollosi et al., 2019; see also Ashby et al. (2017)].

Further, as highlighted by Li et al. (2011) heightened temperatures on the day/days leading up to a study are associated with increased belief in and concern about climate change (Joireman et al., 2010; Egan and Mullin, 2012; Brooks et al., 2014). For example, in one study, belief that climate change is happening was predicted by temperature anomalies (i.e., unseasonable warm and/or cool temperatures) on the interview day and the previous day (Hamilton and Stampone, 2013). However, individuals must attribute these experiences to climate change to not only increase concern for climate change, but also to encourage action (Reser et al., 2012; Akerlof et al., 2013; Myers et al., 2013). That is, when an individual experiences the impacts of climate change (i.e., extreme weather), such experience may not affect their concern or willingness to take action unless they first make a causal connection between the experience and climate change (Weber, 2010; Helgeson et al., 2012). To illustrate, individuals affected by severe flooding in the U.K. in 2013/2014, reported a greater perceived threat from climate change, but only those who attributed the event to climate change supported mitigation actions (Ogunbode et al., 2019). This points to the important role of pre-existing beliefs in shaping people's interpretations and attributions of different weather events.

3.4 Do Prior Beliefs Shape an Individual's Perception of Climate Change Impacts?

Given that a single extreme weather event does not necessarily reflect long-term climate change trends, individuals may rely on their pre-existing beliefs to interpret extreme weather events in terms of climate change. This implies that individuals who already believe in climate change may interpret their experiences as a confirmation of the impacts of climate change. Instead, those who are more skeptical may be less likely to attribute their experiences to climate change (Howe and Leiserowitz, 2013). Such belief-driven interpretations may

reduce the likelihood of some individuals becoming concerned about climate change (Howe and Leiserowitz, 2013; Broomell et al., 2017).

The influence of prior beliefs on climate change perceptions can be explained through a process of directional motivated reasoning. In broad terms, the concept describes how individuals tend to interpret and process information in a biased way that confirms their prior beliefs (Druckman, 2015). Such processing can affect the interpretation of new climate change information and experiences and may motivate individuals to reach their preferred conclusion regardless of accuracy or credibility (Druckman, 2015). The importance of directional motivated reasoning in shaping interpretations of extreme weather events has been documented frequently in recent years (Hart and Nisbet, 2012; Dietz, 2013; Druckman, 2015; Kahan and Corbin, 2016). For example, a national U.S. survey found that respondents who lived in places that were affected by a heatwave in 2010 but were "doubtful" or "dismissive" about climate change were 27% less likely to report experiencing a warmer-than-normal summer (Howe and Leiserowitz, 2013). These findings suggest that motivated reasoning may bias recall of local climate, particularly among those who do not believe in the existence of climate change. Other studies have also indicated that prior beliefs and cultural orientations can bias people's recollections of local weather experiences (Goebbert et al., 2012; Shao, 2016). To illustrate, Shao (2016) found that individuals who believed that climate change is having impacts now were more likely to perceive a strange pattern of weather in the past. Meanwhile, results from a longitudinal survey by Myers et al. (2013) showed that highly engaged individuals (i.e., those who were either strongly convinced of the reality of climate change or strongly rejected it) were more likely than less engaged ones to interpret their personal experiences in a way that strengthened their pre-existing beliefs. It should be noted however, that this and other studies examining the effect of prior beliefs on reported experience of extreme weather events are primarily limited to regions within North America, which has, in recent decades, become deeply divided on the issue of climate change (Carmichael and Brulle, 2017).

Another useful illustration of the role of prior beliefs is research that examines associations between political indicators (i.e., ideology and party identification) and climate change perception (McCright et al., 2014; Hamilton et al., 2015; Zanocco et al., 2018; Marlon et al., 2019). For example, between 2010 and 2014, Palm et al. (2017) showed that Democrats were convinced climate change was occurring and demanded action, whereas Republicans

remained skeptical about climate change. Importantly, such views were generally strengthened over time in both groups, particularly among those engaged with the news and public affairs. This finding is consistent with a process of politically motivated reasoning whereby individuals process information in a way that aligns with their party ideology. Similarly, in a survey across four Gulf Coast states, Shao and Goidel (2016) found that compared with Republicans, Democrats were more likely to believe in the existence of climate change and demonstrated greater concern for future consequences. In addition, Democrats were more likely to notice changes in local weather conditions, including an increase in the frequency and intensity of hurricanes, droughts and flooding.

There is also evidence that motivated reasoning may not affect the recall of all past experiences equally. Memories of abnormal local temperatures are more likely to be shaped by climate change beliefs than other weather types (precipitation), due to the natural link between climate change (global warming) and temperature (Leiserowitz, 2006). Evidence from two national surveys in Norway and the U.S. support this view and find that perceptions of seasonal temperature were shaped by climate change beliefs, political ideology and cultural biases (Goebbert et al., 2012; Howe, 2018). The relationship was substantially weaker for local precipitation, floods, and droughts.

Finally, it should also be noted that the evidence for directional motivated reasoning in the context of climate change beliefs has recently been questioned. To illustrate, Druckman and McGrath (2019) propose that individuals may not engage in directional motivated reasoning when assessing climate change information. Instead, individuals may evaluate new evidence aiming to arrive at an accurate conclusion, independent of their prior beliefs. Still, individuals may vary in how they assess the credibility of new information. Thus, observational studies that consider the evidence of bias or political differences as motivated reasoning should be read with some caution.

3.5 Discussion: Future Research and Wider Implications

We have reviewed the state of knowledge on the links between personal experience, prior beliefs, and climate change concern/action. Although scholars have been researching the topic for more than a decade, our review shows that the empirical evidence remains mixed. There is some evidence that local weather experiences can generate climate change concern, but the capacity for personal experience to promote action may rely upon the experience first

being attributed to climate change (Ogunbode et al., 2019). Attributions may be determined by prior beliefs about climate change, political ideology and/or party identification (Howe and Leiserowitz, 2013). Additionally, the evidence for extreme weather events influencing climate change concern and actions remains limited, with a distinct focus on flooding.

Overall, our review highlights the importance of examining the role of motivational and cognitive biases to help explain how and why weather experiences and prior beliefs may shape individual's climate change perceptions. Behavioral decision research suggests that rare extreme weather events will have limited impact on judgments and decisions, unless they have occurred recently (Konisky et al., 2016). However, even recent events may have limited impact among individuals who hold strong pre-existing beliefs rejecting the reality of climate change (Myers et al., 2013). Existing evidence on the associations between climate change beliefs and perceived weather is consistent with the notion that people interpret and process personal experiences in a biased way that confirms their prior beliefs through a process of motivated reasoning (Howe and Leiserowitz, 2013). However, many of the existing studies report cross-sectional data, making it difficult to determine a causal relationship between personal experience and climate change beliefs. Therefore, as the opportunities for individuals to witness extreme weather events increase, we encourage researchers to utilize a longitudinal and/or experimental design that allow stronger assessments of causality, as studies using such designs are scarce (e.g., Myers et al., 2013; Sobkow et al., 2017). For example, experimental studies could manipulate participants' experience with extreme events in game-like settings (Sobkow et al., 2017) or priming of heat-related cognitions (Joireman et al., 2010).

Differences in methodological approaches across studies should also be highlighted, as the mixed findings outlined may be partly due to such differences. Firstly, some studies use subjective (self-reported) experiences, whereas others examine the influence of objectively measured weather variables on climate change beliefs. Secondly, studies examine a range of independent and dependent variables, which differ in their spatial coverage, time frame, data source and values used. The phrasing of survey questions is also varied, and collectively these differences may in some cases hinder the detection of a relationship between experience and beliefs. Future work could therefore aim to synthesize research designs and methods to aid systematic comparisons, ideally using standardized measures. Finally, most research has been conducted in the U.S. and the U.K. at varying levels (e.g., community, county, state and

national) with a distinct focus on local temperature anomalies and flooding. Future research examining different populations and experiences of different forms of extreme weather (e.g., heatwaves and droughts) would help to examine the generalizability and boundary conditions of the findings reviewed.

Gaining a solid understanding of the mechanism underpinning the associations between prior beliefs, personal experience, and concern and action about climate change (or lack thereof) will be critical for the development of effective risk communication strategies suitable for diverse audiences and may also help to inform debiasing interventions. While communicating about climate change risk and the importance of personal action to adapt and mitigate climate change, we suggest communications should also consider the role of non-analytical processes such emotion, the use of imagery and social/group norms to promote climate change efficacy (Hornsey et al., 2021). More work is needed examining what motivates an individual to attribute a personal experience to climate change (e.g., values, worldviews, social structures etc.) as this has been shown to be a key factor in driving mitigation responses (Ogunbode et al., 2019). The role of affective reactions should also be investigated further, as affective reactions to climate change risks may also be subject to moderation by prior attitudes and beliefs (Swim et al., 2009). Yet, intense negative affect can induce fear in some individuals, and as a result lead to avoidant behaviors and denial (Taylor et al., 2014). Finally, future work should examine in more depth the influence of event recency, personal and financial damages, local warming, and psychological and social contexts; all of which may shape how individuals perceive and interact with weather-related experiences.

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Chapter 4: Outdoor sport in extreme heat: Capturing the personal experiences of elite athletes

Extreme heat inevitably presents challenges to athletes' health and performance. Whilst sport science literature commonly describes experimental work, with a primary focus on the physiological effects of heat, this overlooks the unique insights that qualitative approaches can add. Therefore, this chapter takes knowledge gained from psychological research on personal experience and from robust experimental work in sport science and provides an insight into athletes' perspectives and experiences of extreme heat. Thus, addressing objective 2 of this thesis: to understand elite athletes' perceptions, experiences, and responses to extreme heat in relation to climate change and explore the use of their platforms for climate activism.

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Please note that this paper was published in U.S. English, hence the change of spelling here.

4.1 Abstract

Heat stress from the environment can be detrimental to athlete health and performance. No research, however, has explored how elite athletes conceptualise and experience heatwaves and climate change. Utilising a qualitative approach, this study examined elite athletes' perceptions, experiences and responses to extreme heat in relation to climate change and explored the use of their platforms for climate activism.

Fourteen elite athletes from United Kingdom, Australia, United States of America, Sweden and Canada, who represented ten different sports including race walking, netball and cricket were recruited using snowball sampling. Data was collected using semi-structured interviews. Thematic analysis revealed four broad themes. The first theme reflected uncertainty surrounding the causes of heatwaves and the impact of heat on athlete health and performance. The second theme reflected care and concern for sport and society, including concern for the well-being of athletes and spectators, the impact of heat on facilities and

participation at grass-roots level and how the nature of sport may change in the future. The third theme referred to the implications of heatwave experience on athlete health and performance, and how experience affected individual and organisational preparedness. Finally, the fourth theme referred to enablers and barriers to successful climate change communication.

This study contributes to the sport ecology literature by introducing the subjective heat experiences of elite athletes. By making the perspectives of athletes prominent and acknowledging their lived experiences, we can only truly begin to understand climate-related issues in their holistic sense and may take informed action to address athlete-identified needs. Educating athletes and event organisers about the impacts of heat on sport participation is imperative to increase awareness, and hopefully limit illness for those training and competing.

4.2 Introduction

Climate change is increasing the frequency, intensity and duration of extreme heat events such as heatwaves worldwide (Dosio et al., 2018). Although there is no single internationally accepted definition of a heatwave, broadly defined, heatwaves are extended periods of abnormally hot weather (IPCC, 2018). Heatwaves are a major health hazard to athletes at all levels, especially those who compete in outdoor summer sports such as track and field, cricket and tennis. A growing body of research has highlighted that individuals exercise best in cool, dry conditions with optimal athletic performances typically around 10-15°C (50-59°F) (Oikawa et al., 2021). As environmental temperatures and humidity increase, both cognitive and physical performance deteriorates, to the point where health is negatively implicated. The specific risks associated with extreme heat (i.e., temperatures that are substantially hotter than average) and humidity include heat-related illnesses (e.g., muscle cramping, heat exhaustion and heat stroke; Mountjoy et al., 2012; Yankelson et al., 2014) and performance deterioration (e.g., slower marathon winning times; Miller-Rushing et al., 2012).

Although fatal heat-related injury during sport is rare, several cases of heat-related illness during elite sport have been documented. In 2018, six tennis athletes were forced to retire from the United States Open due to heat stress and exhaustion, while French tennis star, Alize Cornet collapsed at the Australian Open as temperatures soared to 42°C. In the same year, triathlete Jonny Brownlee suffered severe heat exhaustion during the Mexican

Commonwealth Games. The following year, medical staff were on call at the 2019 World Athletics Championships in Doha after 28 athletes failed to finish the women's marathon due to the oppressive conditions. Many athletes suffered a similar fate at the Tokyo 2020 Olympics, with 78 cases of exertional heat illnesses recorded (Soligard et al., 2023). Despite this, outdoor summer sports are generally not suspended even with the presence of extreme heat (Petro, 2011). Instead, organisers commonly introduce precautionary measures such as extra drink breaks. Despite the well-known benefits of increased fluid intake to enhance performance while reducing the risk of developing heat illness, heat and dehydration related problems persist in sport (Bergeron et al., 2005).

It is clear just from these examples the urgent and immediate consequences of extreme heat on elite athletes. This is especially important to recognise in the light of the latest Intergovernmental Panel on Climate Change (IPCC) report, which warns that every increment of warming will intensify heatwaves across most regions resulting in further devastating impacts to athlete health and performance (IPCC, 2023). However, research into the sport-climate relationship is scarce, which is surprising given its global significance and the evident vulnerability of certain sports (e.g., marathon, tennis, road cycling) due to their climate exposed outdoor settings (Orr & Inoue, 2018). A few exceptions have focussed on the role of ski activism in combatting climate change (e.g., Mihala, 2019) and the vulnerability of ski industries (e.g., Scott et al., 2019), but these studies are limited to snow sports with athlete perspectives and climate change receiving little attention (Schneider & Mücke, 2021).

4.3 Literature review

4.3.1 Research on sport and climate

The relationship between sport and the natural environment flows in two ways; that is, sport has an impact on the natural environment, while the natural environment impacts sport (McCullough et al., 2020). Over the past few decades, research exploring the relationship between sport and the natural environment has grown considerably and has recently been termed 'sport ecology' (McCullough et al., 2020). Most commonly, researchers in sport management have focussed on how the sport industry has impacted the natural environment. Examples are largely in the context of the environmental impact of sport (Collins et al., 2007, 2012; Wicker, 2018), sport sustainability (Kellison & Hong, 2015; Sartore-Baldwin & McCullough, 2018) and fan engagement in environmental practices (McCullough & Cunningham, 2011; Casper et al., 2017).

While such studies are important, they do not consider the other half of the sport-environment relationship; that is, the effects of climate change on sport. There are, however, a few exceptions. For example, Scott et al (2022) incorporated perspectives of elite international snow sport athletes and coaches to inform the development of climate indicators and provide new insights into the Olympic competition conditions deemed to be safe and fair. Other research has focussed on climate vulnerability of specific sports, facilities and organizations (Dingle & Stewart, 2018; Orr & Inoue, 2018; Dingle & Mallen, 2020; Orr, 2020). In addition, researchers have investigated climate change risk in the ski industry (Rutty et al., 2017; Scott et al., 2019) and the suitability of cities to host future summer and winter Olympic and Paralympic games (Scott et al., 2019; Ross & Orr, 2021). However, studies of heat impacts and awareness are rare and remain limited to sports tourists (Matzarakis & Fröhlich, 2015) and recreational endurance athletes (Shendell et al., 2010). To date, no research has explicitly examined elite athletes' perceptions and experiences of extreme heat, as well as their engagement with climate activism.

While very little research has examined the impacts of climate change on sport, there is a considerable body of research in sport science which demonstrates the physiological effects of heat on athlete health and performance. Researchers have done so through the lenses of health and performance implications (Miller-Rushing et al., 2012; Mohr et al., 2012; Smith et al., 2018) and the efficacy of coping and mitigation strategies such as heat acclimatisation (Périard et al., 2017; Alhadad et al., 2019; Périard et al., 2021; Racinais et al., 2015, 2021). Nevertheless, not all athletes have the same risk of being negatively affected by the heat. For example, athletes performing in endurance, racket or team-sports events are at greater risk due to the high-intensity and/or long-duration of training sessions, races and/or matches (Mohr et al., 2012; Mountjoy et al., 2012; Yankelson et al., 2014; Racinais et al., 2015). The main factors determining the likelihood of heat-related issues relate to: (1) environmental conditions – temperature, humidity, solar load; (2) intensity and duration of exercise; (3) clothing worn; and (4) individual factors – body size, health status and age (Armstrong et al., 2007). These factors are particularly relevant to sports played outdoors in summer. Cricket, for example, is popular in many hot countries (e.g., Australia, South Africa and India) and involves a range of exercise from near rest to intense exercise. Cricketers also wear a variety of clothing that can act as a barrier to heat exchange (e.g., padding and head protection). Thus, the risk of developing heat-related issues can vary from day to day and

from player to player, and is highly dependent on the type of sport, location and policies in place.

4.3.2 Importance of personal experience

Research in psychology suggests that personal experiences of extreme weather events and/or local weather anomalies such as temperature fluctuations can play a key role in shaping climate change risk perceptions through experiential processing (Weber, 2006; Marx et al., 2007; Spence et al., 2011; Zaval et al., 2014; van der Linden, 2015; Demski et al., 2017). This describes the process whereby negative affective responses to the impacts of extreme weather are attributed to climate change and the salient memories of such impacts heightens perceived risk from climate change (Ogunbode et al., 2019). Behavioural decision research indicates that such experiences provide an opportunity for individuals to witness the otherwise abstract effects of climate change and as such make the risk more tangible and familiar (Lorenzoni & Pidgeon, 2006; Weber, 2010; Spence et al., 2011; Smith & Joffe, 2013; Reser et al., 2014). Although there is mixed evidence about the capacity for personal experience to shape climate opinions (Howe et al., 2019; Sambrook et al., 2021), extreme weather events have been shown in some cases to increase perceived risk (Whitmarsh, 2008; Brulle et al., 2012; Carlton et al., 2016), increase environmental concern and promote action (Spence et al., 2011; Demski et al., 2017; Broomell et al., 2017; Bergquist et al., 2019; Ngo et al., 2020).

The importance of personal experience is yet to be studied in a sport context. However, as previous research has shown, these experiences are important to incorporate as they may not only play a vital role in athlete preparedness for future heatwave events but could also be utilized to help bring the issue of climate change to the fore (Spence et al., 2011; Zaval et al., 2014; Demski et al., 2017). With its global reach, the sport industry has a unique power to capture the attention of and unify a worldwide audience on the issue of climate change; a power that most sectors cannot equal (Orr et al., 2020). Therefore, elite athletes have a powerful opportunity to communicate the urgent need for climate action.

4.4 Present study and research questions

As climate change continues to impact sport, a crucial viewpoint missing from the limited research is that of the athletes themselves. The research questions were therefore motivated by the gaps identified in previous research in sport science / sport management and by

theories in psychology and behavioural decision research, which aim to account for the links between personal experience and climate change risk perceptions. Specifically, personal experience is thought to influence risk perception through its ability to reduce perceived psychological distance of climate change along three dimensions – temporally, socially and geographically (McDonald et al., 2015). Additionally, experiences with extreme weather events may also elicit negative affective responses, which can heighten risk perceptions (Keller et al., 2006).

Therefore, the aim of this study was to understand elite athletes' perceptions, experiences and responses to extreme heat in relation to climate change and explore the use of their platforms for climate activism. Our research questions were: (1) What is the current knowledge and awareness of the causes and risks of heatwaves among elite athletes?; (2) How has extreme heat affected athlete health and performance?; (3) How do athletes and organisers prepare and respond to heat waves?; and (4) Why do elite athletes choose to engage in climate activism or choose not to?

To address these research questions, we conducted semi-structured interviews with elite athletes from the United Kingdom, Australia, United States of America, Sweden and Canada, and explored how they conceptualised and discussed heatwaves and climate change, as well as the implications of experience on health and performance.

4.5 Methodology

4.5.1 Research design

A qualitative phenomenological research design was used, which provided a unique opportunity to capture the in-depth perspectives and lived experiences of participants (Swanson & Holton, 2005). Specifically, semi-structured interviews were used to gain an understanding of the meanings each participant attributed to their experiences, whilst providing the interviewer with the opportunity to probe emergent responses and themes (Saunders & Townsend, 2016). The study and interview materials were granted ethical approval by the Research Ethics Committee of the University of Leeds (LTSEE-122) and all research was conducted in accordance with the Declaration of Helsinki.

4.5.2 Participants

Fourteen participants from a range of countries and sports took part in the study. Brief descriptions of the sports in which they are involved are reported in Appendix B1. Each

participant was assigned a pseudonym to maintain confidentiality. Most participants competed at a national level and/or represented their country at major international competitions such as the Olympic Games. Among the fourteen interviewees, there were 9 males and 5 females, aged between 20 and 41 years (mean = 28.7 years) and most had a university degree. Data collection was brought to an end when no new themes were arising from the data, suggesting thematic saturation had been reached (Bowen, 2008; Saunders et al., 2018). Table 4.1 summarises participant characteristics. Additional participant characteristics are reported in Appendix B2.

Table 4.1: Participant characteristics.

Participant pseudonym	Age group (years)	Gender	Location	Sport	Level of competition	Education
Emma	26-34	Female	Australia	Netball	National	Masters
Andrew	26-34	Male	Canada	Race walking	International	Bachelors
Jack	18-25	Male	United Kingdom	Cricket	National	Bachelors
Michael	26-34	Male	United States of America	Baseball	National	Bachelors
Jessica	26-34	Female	United Kingdom	Field Hockey	International	Bachelors
Oscar	26-34	Male	Sweden	Race walking	International	Secondary
Megan	26-34	Female	Australia	Netball	National	Doctorate
Matthew	26-34	Male	United Kingdom	Golf	International	Secondary
Sarah	26-34	Female	United Kingdom	Rowing	International	Bachelors
Hannah	18-25	Female	United States of America	Rugby sevens	International	Bachelors
Luke	26-34	Male	Australia	Race walking	International	Bachelors
David	35-44	Male	United Kingdom	Canoe slalom	International	Bachelors
Harry	18-25	Male	United Kingdom	Race walking	International	Bachelors
Daniel	26-34	Male	Australia	Australian rules football	National	Masters

4.5.3 Procedure

Participants were recruited through snowball sampling, which allowed approaching elite athletes who may otherwise be hard to reach (Waters, 2015). The call for participation was shared via email to the lead author's existing sport network and via online social media channels (e.g., Twitter and LinkedIn). Participants were eligible for the research if they reported having trained and/or competed in extreme heat conditions and were an active and/or retired competitive elite athlete. Seventeen athletes were approached, and fourteen athletes ultimately participated. For the purposes of this research, elite athletes were defined as athletes competing at international and/or national level (Swann et al., 2015).

Before the interview, participants gave written consent to participate and for the interview to be audio-recorded. All interviews were conducted online in English by the lead author between 31st August 2020 and 2nd June 2021. Each interview lasted between 30-60 minutes (avg = 50 minutes). All interviews were audio-recorded and transcribed verbatim. The interview schedule focussed on five key topics: (1) knowledge and awareness of heatwaves; (2) attitudes and risk perceptions; (3) personal experience and behavioural responses; (4) effectiveness of heat preparation and policies; and (5) climate change activism. To obtain quality data, the lead author used various interview techniques such as careful phrasing of questions, avoiding leading language and using follow up questions (DeJonckheere & Vaughn, 2019; Flick, 2018). The full interview guide used in the study can be found in Appendix B3.

4.5.4 Data analysis

The lead author conducted data analysis, with feedback provided through regular discussions with the co-authors to ensure credibility. Demographic information was recorded at the beginning of each interview to describe the sample in its entirety. A combined technique of inductive and deductive thematic analysis was conducted using NVivo 12, which is defined as a qualitative approach – independent of quantifiable frequency measures - used for identifying, analysing and interpreting patterns within a dataset (Braun & Clarke, 2006; Vaismoradi et al., 2013). The analysis was guided by Braun and Clarke's (2006) established six-phase approach. The first phase - data familiarisation - was achieved during transcription and reading the transcripts. In the second phase, we produced initial codes from the data and in the third phase, the codes were grouped together to form potential themes. In the fourth

phase, the identified themes were then reviewed and refined by: (1) comparing them against the data extracts to ensure they formed a consistent pattern; and (2) re-reading the entire dataset to ascertain whether the themes were representative of the data as a whole. In the fifth phase, each theme and subtheme were defined and named. Finally, the sixth phase involved writing up the article.

4.6 Results

We identified four broad themes and within each, several subthemes emerged (see Table 4.2). The first theme reflected uncertainty surrounding the causes of heatwaves and the impact of heat on athlete health and performance. The second theme reflected care and concern for sport and society, including concern related to the well-being of athletes and spectators, the impact of heat on facilities and participation at grass-roots level as well as possible changes to the nature of sport in the future. The third theme referred to the implications of heatwave experience on athlete health and performance, as well as how experience affected individual and organisational preparedness. Finally, the fourth theme reflected factors that affected the ability of participants to communicate climate change issues to a range of diverse audiences, enablers, and barriers.

Table 4.2: Qualitative themes and subthemes.

Theme	Subtheme
Uncertainty	• Causes of heatwaves • Risks of heatwaves
Care and concern for sport and society	• Human health • Grassroots level sport • Future change to the nature of sport
Implications of heatwave experience	• Impact on performance and health • Impact on individual and organisational preparedness • Recommendations to improve preparedness and mitigate impact on health
Climate change communication	• Enablers • Barriers

4.6.1 Uncertainty

4.6.1.1 Causes of heatwaves

Most participants expressed a great deal of uncertainty about how any of the human and/or natural factors specifically influenced heatwaves, as well as how to define such extreme weather events. Several participants highlighted human-induced climate change as a significant factor in increasing the frequency, intensity, duration, and spatial coverage of heatwaves: “I think over the long term, climate change plays a big, big role in it. But yeah, short term. I don't understand. I don't pretend to grasp how weather works” (Luke, 29, male, race walker). However, a few participants were sceptical of the direct causality between climate change and heatwaves and instead referred to natural processes such as El Niño and high-pressure systems trapping hot air as contributing factors:

> I don't necessarily think that they're [heat waves] caused by climate change. I think that climate change is an impacting factor. To be honest, I don't know how they're caused. My

assumption is that it's some sort of weather phenomenon. But I couldn't be specific as to exactly what causes it. (Daniel, 30, male, Australian Rules football).

4.6.1.2 Risks of heatwaves

Throughout the interviews, it was clear that there was no consistent dissemination of heatwave risk information from coaches, physiologists, or sport organisations. As a result, the knowledge and awareness of the impacts of heat on athlete health and performance varied significantly between participants, with some receiving no information at all. Those competing in long-distance events such as race walking appeared to receive more information about the risks associated with heat (i.e., severe dehydration and heatstroke) compared with less intense sports such as golf. However, participants competing in endurance team sports, which equally require performances to be sustained at a high level for extended periods of time (i.e., rugby sevens, baseball, and Australian Rules football) reported receiving little information. Having access to the latest research (i.e., on pre-cooling strategies) and resources (i.e., heat chambers) was also important, with participants stating the importance of being amongst a team who are extremely knowledgeable and can help them prepare for and cope with the heat: “I have some good connections in the field working on heat strategies or cooling strategies in the heat. So, I do chat regularly with coaches, PhD students and professionals in the area” (Oscar, 30, male, race walker). Additionally, athletes performing at national levels reported receiving significantly less (if any) guidance and information than those competing on the international stage: “Not well informed at all. We haven't really had the science behind heat training or the exposure to heat waves explained to us in any way on any level” (Daniel, 30, male, Australian Rules Football).

4.6.2 Care and concern for sport and society

4.6.2.1 Human health

Most participants who expressed their concern about the impact of heatwaves and climate change on sport and society described similar motivations that tended to underpin these concerns. The first motivation, human health (i.e., athletes and spectators) was most prominent in driving concern and discussion about heatwaves and climate change. Participants frequently used emotive words like ‘scared’, ‘alarmed’, ‘angry’, ‘sad’ and ‘anxious’ to describe the impact of heat on athlete and spectator health and were extremely concerned about the ability of sport organisations to adapt and ultimately provide the best quality heat protection for individuals: “If heatwaves were to happen more often, I'd be

concerned and probably alarmed about the ability of sport organisations to cope with that and be able to adapt their play in a way that kept players safe" (Emma, 31, female, netball).

4.6.2.2 Grassroots level sport

The second core motivation that underpinned elite athletes' concern about heatwaves and climate change was the potential impact on grassroots level sport. More specifically, these participants were concerned about the future resilience of local clubs and facilities and the effect of heat on participation and access to outdoor sports in the future: "if places are getting hotter, and they're getting drier, it will limit who can participate" (Jessica, 27, female, hockey).

4.6.2.3 Future change to the nature of sport

Alterations to the nature of sport was also a motivator and many participants referred to how the heat may affect how some sports are played such as cricket becoming dominated by batsmen, golf becoming a buggy sport and in athletics, endurance races particularly becoming a lot slower, e.g., "I'll forever be the slowest 50k World Championship medallist" (Andrew, 30, male, race walker). In conjunction with the possible increase in schedule changes, rest breaks, shorter matches, cancelled competitions or even sports moving indoors, many participants were worried about the future attractiveness of outdoor sports to athletes at all levels as well as spectators.

4.6.3 Implications of heatwave experience

4.6.3.1 Impact on athlete health & performance

The majority of the participants said their mental as well as physical performance was negatively impacted when they had trained and competed in extreme heat and humid conditions. Optimal physical performance was difficult to maintain, with most participants recalling feeling dehydrated, weak, dizzy, and exhausted resulting in slower matches / races and in some cases leading to withdrawal due to severe fatigue:

> I just hit the wall. I was feeling lethargic, dehydrated, I couldn't sleep well. At the race I think it was 27°C. It was a 5pm race. And I pulled out after 7 kilometres out of 10 kilometres because I was wasted. I was dead. (Oscar, 30, male, race walker).

These participants also noticed a deterioration in their cognitive performance with most noting an inability to focus, communicate and make good tactical decisions, resulting in a higher frequency of errors. From a health perspective, Emma had been left with permanent

damage after suffering from heatstroke during a pre-season netball tournament in Australia. As a result of the damage incurred, Emma was forced to retire from sport and now struggles with day-to-day life especially on hot days: “Since that day, I have not been able to play sport again. […] If it's a hot day, and I go outside, I just lose energy so quick, I just can't really do anything” (Emma, 31, female, netball).

However, participants’ experience of extreme heat during competition or while training was not always negative. Having a comprehensive heat stress prevention strategy (i.e., training in the heat, pre-cooling, and monitoring fluid consumption etc.) in place made a real difference and ultimately reduced physiological strain and optimised both the physical and mental performance of some participants:

> With Doha and actually competing in the heat, it was so much fun. The biggest competitor wasn't any of the other athletes it was the heat and I was confident that I was going to be able to beat the heat. (Andrew, 30, male, race walker).

For these participants, the heat completely changed what was important in their sport. Having complete trust and confidence in both their preparation regime as well as coping strategies significantly minimized the impact of the environment on their racing capabilities.

4.6.3.2 Impact on individual and organisational preparedness

Personal experience of impaired performance and/or a previous diagnosis of exertional heat illness was noted as an important factor that motivated some participants to learn about how to mitigate the effects of extreme heat on health and performance:

> At the time, I didn't have that much experience […] I remember the race getting much harder, much earlier than normal. And the times were a bit slower as well. And then, when I cracked, I really cracked I didn't just fall off pace, but I really fell off pace […] Whereas now I’m training for the Tokyo Olympics and from that previous experience I know that I will have to have an extended heat preparation coming up to the event so that I'm heat adapted and can perform well in the heat. (Oscar, 30, male, race walker).

The importance of learning from experience was clear but with this in mind participants also expressed their concern for younger athletes and – despite their high level of fitness - reflected on their own negative experiences at the beginning of their careers, when they had no experience of performing in the heat and knew very little about preparation and coping strategies:

> At that point I was 21, so I was a bit young and hadn't really thought about how to prepare for a hot weather race. I wasn't really prepared for it, in terms of having many interventions or differing strategies. (Luke, 29, male, race walker).

The lack of experience in hot conditions was a major fear for one participant, who expressed concern about not knowing the signs of or treatments for heat illness: “What worries me is I don't know what they [heat illnesses] feel like. I don't know anything. I don't know if it's starting to happen or if I’m pushing myself too hard” (Hannah, 25, female, rugby sevens).

However, simply gaining valuable knowledge and experience of one hot environment did not necessarily equate to some participants being mentally and/or physically prepared for their next competition in similar conditions:

> Racing in hot conditions is something that I'm at least quite familiar with, I mean even Rio was 28-29°C. But Doha was a different animal. We knew it was going to be hot, but I never understood what that meant until we stepped out of the airport. It was way worse than we'd ever imagined. (Andrew, 30, male, race walker).

Some participants noted that the same temperature felt different from location to location and sometimes experience performing in the heat resulted in a false sense of security.

With a distinct lack of experience and team support, some participants relied on the organisers for guidance on how to prepare for and how to cope in the heat:

> I just kind of trusted that the authorities in place would have everything under control, like I just never really felt that they would do anything that would put us at risk. So, if we're playing it's because it's safe to do so. (Emma, 31, female, netball).

However, the organisational response and the safety measures that were introduced seemed to be dependent on the level of competition. Those participants who had competed at The World Athletics Championships in Doha for example referred to an abundance of measures put in place to ensure athletes could cool down properly e.g., multiple drinks stations with ice cold water, ice towels, ice baths, ice jackets, shaded areas and trained medical professionals on standby in case of emergency. Though, this was not always the case at other competitions on the international stage, where it was the responsibility of the individual, the team and/or the sport governing body to supply athletes with cooling equipment and garments. Harry spoke of the inequality between athletes that resulted from not having access to the same knowledge and resources of a larger team. In contrast, participants reported a sheer lack of safety

measures at lower levels of competition (i.e., regional, and national), with several participants recalling having access to just one or two cooling methods e.g., cold towels and water.

Interestingly, the level of individual and organisational preparedness was sometimes dependent on whether the hot conditions were expected. Emma and Luke referred to events where the conditions were abnormally hot for the time of year and the location, which resulted in athletes, coaches and the organisers being less prepared, meaning fewer coping strategies were put in place to protect the health and well-being of athletes and spectators:

> Shepperton because it's not traditionally a hot place, I don't think anyone was going into it thinking, this is going to be a really hot event, let's acclimatize. None of the protocol was in place. There weren't any ice vests or any of that kind of technology or even frozen bottles. It was pretty scaled back compared to what I have seen deployed on different events, when people know that it's going to be hot. (Emma, 31, female, netball).

4.6.3.3 Recommendations to improve preparedness and mitigate impact on health

Five themes of recommendations with subthemes were developed from the interviews including: education, policy, planning, role of the athlete and data availability (Table 4.3). Recommendations regarding education were for the dissemination of information regarding heat risk and protection. Policy-based recommendations explicitly mentioned policy or guidelines for managing heat. The planning theme included recommendations that were aimed at being prepared to deliver a sport event in extreme heat conditions. The role of the athlete theme mentioned sport organisations empowering athletes to speak up about their experience with the ongoing and future impacts of climate change. Finally, recommendations regarding data availability were those that asked for better monitoring and documentation of heat-related illness during sport events.

Table 4.3: The key heat recommendations suggested by participants.

Theme	Sub-theme	Thematic overview
Education	Heat-risk awareness	Education strategies focussed on the risks of heat to athletic performance and health, as well as information regarding adequate nutrition and hydration practices.
	Mitigation strategies	Before events occur, organisers should reach out to the athletes and teams about preparation strategies to ensure that everyone is knowledgeable and well-equipped for the hot conditions.
Policy	Heat threshold and warning systems	Early warning system (understandable to a lay person) that notifies organisers to follow a heat protocol for their event, which allows for proper preparation to be put in place.
	Policy development	All sport governing bodies to develop science-based heat policies to protect athletes and spectators from the risks of extreme heat.
	Sport-specific guideline development	Sport organisations and/or federations to release guidelines for sport at all levels on how to organise events during hot weather conditions.
	Athlete centred policies	Athlete health to be put at the heart of sport organisations agendas
Planning	Scheduling	Scheduling events at cooler times of the day (i.e., morning or evening) that is safer for athletes, rather than selecting a time that will have the largest TV audience.

	Equipment	Organisers to set up cooling facilities such as ice baths for before and after events, allowing athletes that do not have access to the resources of a bigger team to utilise the intervention.
	Venue provisions	Organisers to provide ice cold water and shade wherever possible
Role of the athlete	Support outreach	Sport organisations and/or federations to create a healthy environment for athletes to speak about their experiences performing in extreme weather as well as their relation to climate change – without fear of judgment
Data availability	Heat illness evidence base	Organisers to document the occurrence of heat-related illness during events to gain an understanding of incidence rates

4.6.4 Climate change communication

Most participants used their platforms, albeit at varying degrees, to talk about the issue of climate change. Platforms included social media channels such as Twitter or Instagram, key sport events, and climate action groups such as EcoAthletes. Participants identified a range of environmental and individual factors that affected their ability to communicate climate change issues to a range of diverse audiences. These were categorised into five overarching enablers and six overarching barriers to successful climate change communication. Table 4.4 summarises each factor.

Table 4.4: Enablers and barriers to climate change communication.

Enablers	Education Having a real story to tell Power of the athlete voice Care for the environment and future generations Sense of duty and responsibility
Barriers	Knowledge and education Fear of judgement No plan B Climate change scepticism Small platform Distraction from other issues

4.6.4.1 Enablers

Education was considered crucial by most participants to not only build knowledge, awareness, responsibility, and behavioural intention regarding climate change but also to empower them to speak about the issue with passion and confidence to their sport communities. Through reading and learning, participants understood climate change to be a serious threat to themselves, their families, and their sport, while a few also alluded to the crisis exacerbating other issues such as global inequality:

> I think it's the greatest threat to humanity. And there are lots of other issues that I care about, like equality and poverty and racial justice and the justice system in general but all of these are, I feel hinge on us having a healthy environment to live in and on. (Sarah, 27, female, rowing).

The second factor enabling some participants to communicate the climate change issue with ease was having a real story to tell that people could relate to. Emma spoke of her own heatwave experience, and even though it forced them to retire from their sport, it also offered a more personal, powerful and meaningful way to connect and engage with others on the topic of climate change: “It's a real story that other people can connect to. I think for me, it makes it a bit easier, because I can just be real and speak on my own experience” (Emma, 31,

female, netball). Using a narrative form of communication became a window into their world, which was key to starting a conversation about climate change and ultimately creating the space for other people to follow with their own experiences. Additionally, other participants often mentioned the power of the athlete voice as an equally important tool to raise awareness of the climate crisis and potentially encourage their followers to take action: “I believe that sport can be a vehicle for change, and that athletes have the power to give voice to organisations or individuals who otherwise would not be heard” (Daniel, 30, male, Australian Rules Football). The source of their power to inspire and affect change was described as a result of the attributes they convey such as resilience, ambition, innovation, leadership, and self-sacrifice, which draw admiration from fans. However, a few participants struggled to find the right way to use their voice and disagreed about the extent to which their voice could be a catalyst of change: “I just don’t think I am a person that is going to sway anyone’s decision making on the topic, and therefore speaking about it tends to feel very performative” (Andrew, 30, male, race walker).

The importance of caring for the environment and protecting future generations was also frequently discussed. Several participants referred to their own experiences of being able to explore their full potential as athletes and being able to develop, grow and learn in a healthy environment. These participants were therefore motivated to use their powerful voices to speak about climate change to ensure that children of present and future generations were granted the same experiences and opportunities, especially in sport:

> I want good things for people, because of the experiences I've had. I want people to enjoy the power of sport, I want people to enjoy my sport in the future. But none of those things are going to happen if we continue what we're doing. (David, 41, male, canoe slalom).

4.6.4.2 Barriers

Although education was referred to as a powerful enabler that empowered participants to speak about climate change, it was also viewed as one of the main internal barriers. A lack of knowledge and understanding of the physical climate science, as well as how to communicate the issue effectively, impeded – and in some cases prevented - several participants to speak about climate change:

> It’s just something that is a bit beyond my depth. I understand things at a very basic level but certainly not enough to engage in meaningful discussions online with people who have a differing opinion. (Andrew, 30, male, race walker).

These participants frequently spoke of the need to “be perfect to speak out”, and if this was not the case, they feared public ridicule and scrutiny not only for speaking about a topic that they did not completely understand, but also for being accused of hypocrisy for their high-carbon lifestyles. By using their platform to speak about climate change, other participants feared being in the spotlight, especially if they were under-performing in their sport: “It's hard to be that guy that's trying to send out a different message when you know, it's easy for a fan to go back and say, focus on your cricket, you're not doing very well at the moment” (Jack, 23, male, cricket). Similarly, Emma and Megan spoke of teammates who were defined by their sport and ultimately had *“no plan B”* and therefore were afraid to express their feelings about climate change through fear of jeopardising their careers or losing funding: “Netball is a sport that struggles to get funding, sponsors and even coverage. So, no one will want to put that at risk not just for themselves, but for everyone else that's playing*”* (Emma, 31, female, netball).

Although most participants were keen to openly discuss climate change, Matthew and Harry were extremely sceptical about its existence - explaining how “there's not enough scientific evidence it’s happening*”* (Matthew, 31, male, golf). Both participants stated a need for more scientific evidence and a greater number of high-profile athletes engaging in climate change advocacy to encourage others who have not spoken out about climate change. Given their small platforms, some participants were also sceptical of their individual ability to be heard and ultimately encourage action, with many identifying the need for governing bodies to step up and safeguard the future of sport: “My individual ability to influence this is limited, because we need system level changes” (David, 41, male, canoe slalom). However, one participant feared being heard as it may distract attention from other issues such as racial justice:

> In America, a lot of athletes are rightfully bringing attention to like the Black Lives Matter movement. And so, I guess it can feel like as an athlete, if I'm complaining about climate change am I distracting from them or taking away their time? (Luke, 29, male, race walker).

4.7 Discussion

The Intergovernmental Panel on Climate Change (IPCC) has published several comprehensive reports highlighting the state of the current climate, its impacts and how these

changes will interact with human and environmental health in the future. The latest report indicates that global surface temperature was 1.09°C higher in 2011–2020 than 1850–1900, increasing the frequency and intensity of heatwaves across most land regions (IPCC, 2021). Exercising under such extreme environmental conditions will increase the likelihood of developing exertional heat illness, affecting athletes' coordination (Muniz-Pardos et al., 2019), reducing cognitive function (Lieberman et al., 2005), impairing performance (Nybo et al., 2014) and in some cases leading to heatstroke and collapse (Kenefick & Sawka, 2007). Despite this, in the current study we found that the knowledge and awareness of the impacts of heat on athlete health and performance varied significantly and appeared to be associated with sport type, access to research and resources, athlete level and personal experience.

Our findings provide a unique understanding of how elite athletes conceptualise and discuss heatwaves and climate change, as well as the implications of experience on their health, performance, and sport in general. Specifically, our findings highlight how elite athletes are often uncertain about the cause, impacts, and urgency to address heatwaves and climate change. We found a clear division in knowledge and awareness of the risks of heatwaves, which seemed to be related to sport type, access to the latest research, athlete level and personal experience of impaired health and performance. These factors – along with the expectance of abnormally hot temperatures - were often related to the level of individual and organisational preparedness. Despite the uncertainty and distinct divide in knowledge, our results indicate that athletes are generally aware that heatwaves and climate change create an ongoing struggle for sport and future generations, with concerns that further warming will negatively impact human health, grassroots sport, and participation. With this in mind, the majority of athletes were motivated to use their platforms (albeit at varying degrees) to talk about the issue of climate change and identified a range of enablers and barriers that affected their ability to communicate climate change issues to a range of diverse audiences.

On the one hand, it seems athletes need more knowledge and education on heat, climate risks, and ways to prepare, but on the other hand, there is also evidence that people do not actually act until they have had a significant experience of heat. However, the relationship between one's knowledge and decision-making in weather-related scenarios is complex. Research has shown that knowledge does not necessarily lead to action, and it is difficult for facts alone to change individual or collective behaviours (Suldovsky, 2017; Knutti, 2019). As such, the provision of information, regardless of its accuracy, will not be enough in most cases.

Further, people who know the least about a topic are often very overconfident of their knowledge while those who know the most often underestimate their knowledge (Casteel, 2023). Although more education is needed, the findings suggest a conundrum. Those who know the least about severe weather, thinking they know a lot, are probably those individuals least likely to seek out additional education on the topic. This means that education could be difficult to implement if knowledge confidence is already high. Further, even if organisers were to provide education and guidelines on heat preparation, it is not mandatory and the cost of accessing the right facilities and equipment is significantly high. Therefore, funding, and greater education of low-cost options will be needed to increase athlete's ability to adopt heat measures.

Alternatively, the experience of the negative consequences of heat on health and/or performance may provide more of an incentive than information alone, suggesting that an athlete's actions may be more reactive than proactive out of necessity. However, this does also suggest that if an athlete's health and performance hasn't been impaired by extreme heat, they are highly unlikely to invest the time and money in preparatory measures (Esh et al., 2024). Therefore, it is vital that future research focusses on capturing the athlete voice and exploring perceptions of heat measures as well as identifying the enablers and barriers in adopting them, and specifically how these can be overcome.

To the best of our knowledge, this is the first study to explore how elite athletes conceptualise and experience heatwaves and climate change. In contrast, previous research on climate opinion has predominantly focused on the effect of local weather anomalies and extreme weather on climate change beliefs among the general public, often using a quantitative approach. The current qualitative interview-based approach focusing on elite athletes makes an important contribution to the sport ecology literature by introducing the subjective heat experiences of athletes. Previous work has focussed on the physiological effects of heat on athlete responses and performance (Mohr et al., 2012; Donnelly et al., 2016), but our results demonstrate the necessity of a qualitative research approach to fully understand the rich and multi-faceted experiences of extreme heat and climate change. Specifically, the qualitative approach used allowed a more in-depth exploration of experiences, and associated feelings and emotions. With a distinct focus on elite athletes and extreme heat, this research provides an in-depth understanding of the ideology surrounding climate change across sport communities and extends the literature on personal experience and climate opinion

(Whitmarsh, 2008; Spence et al., 2011; Akerlof et al., 2013; Demski et al., 2017; Bergquist et al., 2019). By making the perspectives of athletes prominent and acknowledging their lived experiences, we can only truly begin to understand climate-related issues in their holistic sense and may take informed action to address athlete-identified needs. As such lived experience knowledge can be used to urgently develop appropriate climate adaptation strategies to effectively safeguard athlete health and prevent inequities from widening. Further, by uncovering and shining a light on physical and emotional wellbeing, issues may increase awareness of the extent of our climate emergency amongst the public and policymakers, which may push sport organisations to develop and implement urgent adaptation and mitigation strategies.

The impact of heat on sport performance is closely linked to the duration of the event with a larger decrease in performance during endurance events (Bouscaren et al., 2019). Such events are often described as compromised by the heat (Taylor, 2000; Guy et al., 2014) and athletes taking part in long-distance events can be at risk of substantial dehydration and overheating (González-Alonso et al., 1999). This may explain why such athletes were often knowledgeable and aware of the risks of heat to their health and performance. Athletes competing at international levels also reported receiving guidance on heatwave risk, whereas those competing at national levels often reported receiving little guidance. International sport competitions are increasingly being held in hot and/or humid cities such as the 2019 World Athletics Championships in Doha and the 2020 Olympic Games in Tokyo. Therefore, in recent years, nations and governing bodies have committed more time, research and resources to enable athletes to cope with the challenging conditions and to develop effective strategies that can be applied during the competition to optimize performance and reduce the risk of heat-related illness (Griggs et al., 2020). Nevertheless, our research indicates that the negative effects of heat are widespread and may not be exclusive to a specific sport discipline or athletes of a particular age or fitness level. This is consistent with previous research showing that the risk of developing exertional heat illness is also elevated in shorter races and field events (Périard et al., 2017) as well as team sports such as football (Mountjoy et al., 2012; Racinais et al., 2012).

Personal experience of heat illness and/or impaired performance often motivated participants to improve their knowledge and understanding of how to prepare for and perform well in hot environments. The impact of high temperatures and humidity on performance and the risk of

heat-related illness can vary significantly from person-to-person contingent on a wide range of chronic and acute individual factors such as body size, degree of acclimatisation, hydration status and heat production (Armstrong et al., 2007). Therefore, the most effective coping strategies that meet the needs of each individual are typically only learned by repeated exposure to the heat and trial and error (Maughan & Shirreffs, 2004). These findings are in line with a previous cohort study examining the strategies and factors associated with preparedness for competing in the hot and humid conditions at the 2015 World Athletics Championships in Beijing (Périard et al., 2017). The results indicated that the adoption of a combined heat stress prevention strategy (e.g., acclimatisation, pre-cooling, and hydration) strongly depended on a previous diagnosis of exertional heat illness and on the sex of the athlete. However, specific heat stress prevention strategies such as heat acclimatisation prior to the championships were uncommon even among athletes with previous experience of exertional health illness symptoms. Accordingly, a better understanding of the factors that influence the preparation and adoption of specific coping strategies is clearly warranted.

Despite the importance of learning from experience, our research also indicates that not all athletes have sufficient experience of hot and humid conditions in order to fully understand how they will respond to heat stress and accordingly develop their own coping strategies. Without proper knowledge and experience, younger athletes may not realise the early signs and symptoms of exertional heat illness and as a result continue competing. This ‘warrior mentality’ or internal motivation to push oneself could further increase the risk of exertional heat illness in athletes who have not prepared adequately (Hosokawa et al., 2014). Risk factors for exertional heat-related illness may be internal or external, including younger age and poor education about exertional heat-related illness and prevention strategies (Nichols, 2014). These individual risk factors – among others – will likely only worsen the burden of thermally stressful environmental conditions with unequal consequences, highlighting how excessive heat may exacerbate inequality among athletes at all levels. Therefore, it is imperative that all athletes – regardless of sport type, level, and experience - receive information and guidance on various preparation strategies ahead of a competition expected to take place in hot and/or humid conditions.

Given the expected increase in heatwaves, many participants expressed their concern about climate change by referring to emotions such as ‘scared’, ‘alarmed’, ‘angry’, ‘sad’ and ‘anxious’. Negative emotional responses toward climate change can play an important role in

driving climate change perceptions and actions (Brosch, 2021). The high presence of emotional responses was coupled with a concern for human health and youth participation, the ability of grassroots level sport to maintain facilities and the future of sport as we know it. This aligns with findings from the quantitative literature indicating that "objects of care" such as future generations and the environment can motivate caring about climate change (Wang et al., 2018). Accordingly, future research might explore how emotions influence the decisions and actions of athletes on climate change. In the absence of sufficient rest, hydration, nourishment, and acclimatization etc., the ability of younger athletes to tolerate hot environments is significantly reduced and consequently, the risk of developing exertional heat illness is elevated (Bergeron, 2015). Previous research conducted in the United States has shown that the diagnosis of exertional heat illness has increased in young athletes and is the leading cause of death at youth level sport, with the majority associated with football (Maron et al., 2009). Every individual is different and the ability to adapt to the heat will vary, which may have implications for team selection for example. Accordingly, extreme heat could present significant challenges to youth participation and equality at present and in the future, especially if sport shifts from one of athletic skill to one of heat endurance.

Regarding climate change communication, our research detected a small but growing pool of elite athletes who have been outspoken on environmental and climate issues. Several factors that enabled climate change communication were identified, with knowledge and awareness of climate change being considered the most important. This is in line with previous research that has shown that knowledge of climate change consequences and concern about the future of lifestyle sports such as skiing, and snowboarding can motivate activist behaviour (Mihala, 2019). However, participants also raised concerns and barriers to using their platform to speak about climate change. Considering all this and given the power of narrative forms of communication, it may be useful to amplify athletes' stories to show that people may in fact be successfully involved in sport, strongly identify with the athlete role, and communicate the issue of climate change. Accordingly, this could create spaces for athletes who may be intending to engage in climate change, to discuss their apprehensions in safe environments where there is minimal risk of being judged. It may also provide opportunities to discuss concerns about engaging in climate change, such as losing support from sponsors.

The diversity of barriers identified indicates a need for a comprehensive strategy to foster engagement amongst athletes. Basic information provision to overcome lack of knowledge

about climate change highlighting implications for athletes and sport is critical to empower individuals to speak out. With these obstacles in mind, several sports-focused climate organizations have already been established such as EcoAthletes, which identifies, coaches, and deploys athletes to talk about climate change. By equipping athletes with appropriate knowledge and skills, it is hoped that more will be encouraged to overcome the identified barriers and use their platforms to lead on climate change action.

4.8 Limitations and Future Research

As with any research, ours is not without limitations. Our interviews enabled us to gain an in-depth perspective of elite athletes' experience of heatwaves, but the results should be interpreted with caution given the small sample, snowballing approach and the absence of multiple coders which could reduce reliability. Future research involving larger samples could examine how perceptions and experiences of extreme heat and climate change may differ between sports, gender, level of competition and nationality. Future work could also involve athletes from Asia, Central and South America, and Africa as well as athletes who practice other outdoor sports such as tennis, triathlon, and football. In addition, given the potential power of the sport community to inspire and accelerate climate action, future work should continue to assess the role of elite athletes in communicating climate change. Finally, due to existing quantitative studies having a distinct focus on public experiences of flooding (Sambrook et al., 2021), this study was purposefully confined to elite athletes and extreme heat. Future work could examine perceptions and experiences of other climate impacts such as hurricanes and droughts among the wider sport community, which remain poorly understood.

4.9 Conclusions

This exploratory study of extreme heat and outdoor sport has provided a unique insight into the perspectives and experiences of elite athletes. We can only fully begin to comprehend climate-related concerns in its comprehensive sense by elevating the views of athletes and recognising their lived experiences. Only then will we be able to take informed action to meet the needs indicated by athletes. As sport organisations address the impact of climate change, it is important that athletes, coaches, and event organisers receive more education about the impacts of heat on sport participation to increase knowledge and awareness, and hopefully limit illness for those training and competing. In addition, as more athletes use their popularity to shed light on climate change, it is hoped that this study will inform sport

organisations on how they can support and empower athletes to communicate the issue. The findings speak to the importance of a sport narrative around extreme heat that includes climate change. Using sport to communicate about the risks of extreme heat and other extreme weather events may provide a powerful narrative about climate change impacts for engaging fans and wider audiences about rising climate risks.

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Chapter 5: The role of sport in communicating the impacts of climate change

Climate change and its impacts can be challenging to communicate and therefore it's important to think of creative ways to engage diverse, non-scientific audiences. Several researchers have suggested that using narratives could be one way to address this problem. Taking this into account, the previous chapter highlighted that elite athletes have powerful narratives to share but many were unsure of how and if to communicate their stories. Therefore, building on the actual heat experiences that were extracted from the interview study, this chapter addresses objective 3 and explores the impact of a sport narrative on risk perception and emotional responses to extreme heat and climate change compared to other message types. This paper was presented at the International Conference on Environmental Psychology at Aarhus University in Denmark in June 2023. The intended journal for this paper is the Journal of Environmental Psychology.

5.1 Abstract

Athletes are already suffering from the direct impact of extreme heat. Sharing these personal experiences could be an effective communication strategy to engage diverse audiences on the risks associated with heat and climate change. Yet the potential effects of sport narratives are under-researched; this paper addresses this gap. We conducted an online experiment with a nationally representative UK sample (N=713) to understand how a sport narrative could impact risk perception and emotional responses to extreme heat and climate change. Participants were presented with an online survey comprising of six sections (i.e., climate change risk perception, heatwave risk perception, emotional response, sport fandom, numeracy and socio-demographics). One week later, the same participants were randomly assigned to one of five message groups – basic heatwave information, statistical information only, lay person narrative, sport narrative and control respectively (no information). After reading the short message, participants were presented with the same survey as the pre-test study with the addition of questions on perceived informativeness of the message and short-term behavioural response.

Relative to the control group, the statistical information only group showed significantly higher means on climate change risk perceptions ($p = .038$), and the sport narrative group

reported significantly higher heatwave risk perceptions (p = .008). We found no significant message type effects on participant's positive emotional responses (p = .28) and negative emotional responses (p = .817). The findings speak to the importance of emphasizing both scientific findings and individuals' personal experiences when designing climate messages. Using sport to communicate about the risks of extreme heat may provide a powerful narrative about climate change impacts for engaging fans and wider audiences about rising climate risks. The implications of these findings for developing more engaging climate change narratives are discussed.

5.2 Introduction

Sports teams and athletes are already witnessing and suffering from the direct impact of extreme heat and climate change (Bernard et al., 2021; Orr et al., 2022). However, sport is rarely used as a vehicle to communicate the severe consequences of climate change to the public. Instead, climate change has historically been framed as a scientific/environmental issue, and more recently as a political issue, often communicated using statistical information, which has been ineffective in engaging a broad cross-section of audiences (Dahlstrom, 2014; Jones, 2014; Badullovich et al., 2020).

Effective communication to diverse, non-scientific audiences requires alternative approaches and several researchers have highlighted that narratives may be part of the solution (Böhm et al., 2019; Hinkel et al., 2020). In this context, "narratives are a means of communicating information about something that has happened by concentrating on the causal linkages between events and usually centre on a character or characters that drive the action" (Cooper & Nisbet, 2016, p. 629). There is growing interest in how narratives may be used as forms of evidence and communication within climate change research (Dahlstrom, 2014; Moezzi et al., 2017). Prominent narratives range from 'doom and gloom', which emphasises the adverse impacts and costs of climate change, framing climate change as an 'emergency', to viewing climate change as the most critical issue facing future generations (Bevan et al., 2020; Hinkel et al., 2020). In the context of climate change, it is widely acknowledged that engagement with relatable characters can help increase the emotional response to narratives which is key to shifting climate change risk perceptions (Jones, 2014; Gustafson et al., 2020), and in some cases increasing support for pro-climate policies and inspiring individual and collective climate action (Sabherwal & Shreedhar, 2022).

Previous research has found that weather variations may be associated with people's concern over climate change (Joireman et al., 2010; Egan & Mullin, 2012; Deryugina, 2013; Hamilton & Stampone, 2013; Shao et al., 2014, 2016; Shao, 2017). For example, three studies carried out in the US over a ten-year period discovered a link between increasing summer temperatures and a belief in the severity and rapid effects of climate change (Shao et al., 2014; Shao, 2016). However, according to Taylor et al (2014), in the UK, people's concerns about climate change are often more strongly related to their perceptions of the possibility of increasingly wet weather. This indicates that UK residents may have positive emotions towards hot weather, but not wet weather (Palutikof et al., 2004; Lorenzoni & Pidgeon, 2006; Taylor et al., 2014). However, people considerably misjudge the risks posed by such intense events because they have a positive attitude towards heatwaves (Finucane et al., 2000). More recently, research has shown that concerns about climate change and extreme weather may in fact develop in different ways (Findlater et al., 2018, 2019; Bruine de Bruin & Dugan, 2022). For example, Bruine de Bruin and Dugan (2022) has shown that compared to extreme weather concerns, climate change concerns were strongly linked to education, with people who had attained a college or high-school degree showing more concern for climate change. However, education was not linked to extreme weather concerns. Instead, there was a stronger relationship between people who had experience of extreme weather events and concern about extreme weather. Therefore, it’s important to understand how people perceive the risks posed by both extreme weather (i.e., heatwaves) and climate change.

Research appears to show a consistent pattern on the influence of individual-level factors on climate change perceptions (i.e., men, older age groups, those who support conservative parties, and those with lower education levels tend to be less concerned about climate change: Whitmarsh, 2011; Shi et al., 2016). A growing body of research has examined the consequences of increasing climate change risk perceptions. It has been shown that climate change risk perception is positively correlated with both adaptation and mitigation actions (Azadi et al., 2019; Jakučionytė-Skodienė & Liobikienė, 2021). This suggests that climate change risk perceptions can serve to encourage actions that help to address climate change more effectively (Wang et al., 2021).

Sports stories are among the many relatable and personalized narratives that can connect people to the climate crisis in various ways. With its extensive social platform, sport can offer

a tool for inclusion and connection. Billions of individuals worldwide are involved in sport and thus it can be used as a powerful tool to break down socio-cultural barriers within communities and influence people's attitudes on environmental issues. As such, sport could play a key part in increasing knowledge and awareness about climate change (Trendafilova et al., 2013). In particular, with their vast following, individual athletes and teams could serve as role models with the goal to raise awareness about climate change among their fan base (Haslett et al., 2020). In recent years, athletes have been increasingly active in lobbying for sport organisations to take action on climate change: in 2021, more than 50 Olympians and Paralympians called on world leaders attending the 26th United Nations Climate Change Conference of the Parties (COP26) to recognize the impact of climate change and to take action now. Similarly, in 2014, 105 winter Olympians signed a petition urging world leaders to take climate action (Gruneau & Horne, 2015).

The unique ability of sport to create a high level of passion and identity (Babiak & Wolfe, 2009) could greatly influence individuals' engagement with climate change and provide a powerful narrative for sport organizations to engage and unify a worldwide audience about rising climate risks (Casper et al., 2015). Using sport as a platform to highlight important societal issues is not new, with many athletes and sports teams continuing to take the knee to show support for the 'Black Lives Matter' movement and raise awareness about racial inequality and injustice (Evans et al., 2021). However, to our knowledge, there is no research about how sport narratives could influence risk perceptions and emotional response in the context of heatwaves and climate change. In this article, we build on previous research investigating the persuasive powers of narratives to shift risk perceptions and emotional responses. Using an online experiment, we test whether using a sport narrative produces an impact on risk perception and emotional response to heatwaves and climate change, compared to other messages. These messages included: (1) basic heatwave information; (2) statistical information only; and (3) a lay person narrative.

5.3 Framing climate change for effective communication

5.3.1 Importance of narratives

Communication has a critical role to play in raising awareness and provoking action on climate change. However, simply highlighting the scientific evidence for climate change is generally insufficient (Dahlstrom, 2014; Jones, 2014). Instead, scholars have proposed that making the impacts of climate change more personally relevant could increase engagement

(Weber, 2006), with many highlighting the use of narratives as a promising strategy of effective climate change communication (Böhm et al., 2019; Badullovich et al., 2020). Thus, narratives can be used as evidence to support or even enhance persuasive climate messages as they commonly highlight the personal experiences of others, which may be difficult to challenge (Bekalu et al., 2018; Shaffer et al., 2018; Bullock et al., 2021). Further, through their vivid, engaging and emotionally charged representations of particular issues and/or events (Slovic et al., 2004), narratives may be particularly effective in reducing psychological distance, thereby increasing emotional engagement and personal risk perceptions (Van Boven et al., 2010; Lu & Schuldt, 2016).

To explain the persuasive influence of narratives, several theories have been proposed such as transportation theory (Green & Brock, 2000) and exemplification theory (Zillmann, 1999). Narrative transportation theory proposes that when people are highly engaged and absorbed by a story, their beliefs, attitudes and behavioural intentions may change to reflect that of the character (Murphy et al., 2013). As such, the effect of transportation is that people are able to identify with the character and take on their perspectives, emotions and motivations that direct their behaviour. Therefore, transportation may make a narrative experience feel more like a real personal experience and thus elicit stronger affective responses (Green & Brock, 2000; van Laer et al., 2014). Similar to transportation theory is the exemplification theory. Exemplification theory considers the persuasive effect of personal stories (exemplars) compared to statistical information when presented in news reports. Research suggests that the use of exemplars can have a stronger impact on attitudes and behavioural intentions, compared with traditional fact-centred news reports (Daschmann, 2000; Boukes et al., 2015). For example, Gibson and Zillmann (1994) found that when narrative and statistical information appeared in the same news report, people's perceptions of a social phenomenon were more influenced by the specific narratives, with the persuasive effects attributed to the exemplars vividness and ability to create an emotional response.

5.3.2 Mechanisms of narrative persuasion

Research examining the effect of narratives and statistical information on preferences and attitudes spans several fields, but there is no consensus to date on the persuasiveness of narrative and non-narrative messages on risk perceptions, emotions and behavioural intentions. In social sciences, theoretical and empirical work has demonstrated that narratives rather than scientific facts often represent people's understanding of climate change (Lowe et

al., 2006; Jones, 2014). In science communication, it has been found that personal climate change stories can increase climate change beliefs (e.g., belief that climate change is occurring and is being caused by human activities) and risk perceptions (Gustafson et al., 2020). In some cases, they have been shown to promote pro-environmental behaviour such as recycling (Morris et al., 2019), with emotion being acknowledged as an important factor driving the persuasiveness of narratives (Nabi & Green, 2015). Similarly, research in health communication has found that narrative communication can play an important role in shaping opinion, attitudes, behaviours, and perceptions of risk (Winterbottom et al., 2012; Braddock & Dillard, 2016; Shaffer et al., 2018). For example, the inclusion of narrative information in an online health program for breast cancer patients significantly increased healthcare participation compared to traditional, didactic forms of communication (Wise et al., 2008). Further, one study examining HPV risk perception has suggested that a hybrid of narrative and statistical evidence is more effective at increasing perceptions of risk than just one type of evidence (Nan et al., 2015).

Theoretically, narratives can help close the psychological gap between the audience and the issue (climate change, for example) that the message is trying to address (Maiella et al., 2020). More specifically, narratives often provide specific cases in addition to in-depth descriptions of characters and scenes (Slater & Rouner, 2002; Braddock & Dillard, 2016). These particular situations could provide people with points of reference to start mental simulation and think back on their own experiences (Green & Brock, 2000). According to this theory, it is expected that a person's experience of extreme weather occurrences should be magnified or given more significance if they have a strong connection to the character. For instance, an experience is more likely to be magnified and so more prominent in people's concerns if it is perceived in terms of empathy with others who have been impacted (Brügger et al., 2021). This suggests that narratives about extreme weather experiences could heighten feelings of risk, which should raise negative emotions and motivate the person to look for more information to comprehend the event (Keller et al., 2006; Lujala et al., 2015; Yang et al., 2015).

Whilst we have an understanding of the effect of lay person narratives in science and health communication, it remains unclear how an athlete narrative about the impacts of extreme heat and climate change may impact risk perceptions. With an increasing number of athletes sharing their experiences of / opinions on extreme weather and climate change, it is important

to understand how impactful their messages might be to inform and possibly shape future communication efforts compared to other message types.

5.3.3 The role of numeracy and sport fandom

How people respond to different narratives may depend on several factors. For instance, an individual's capacity to process numbers has been shown to impact judgments and decisions involving risk (Peters et al., 2012). Numeracy is the ability of a person to comprehend and analyse the fundamental probability and numerical data needed to make decisions. Peters et al (2012) has shown that higher numeracy is often linked to decreased vulnerability to framing effects, increased sensitivity to numbers, and less reliance on nonnumerical information, which usually leads to better decisions. For example, in health communication research, it has been shown that narratives may be especially persuasive and helpful to people with low numeracy as they tend to perceive this form of communication as more informative compared to statistical information and vice versa (Dieckmann et al., 2009; Peters et al., 2009; Bruine de Bruin et al., 2017).

Another factor that may affect people's responses to narratives is their level of interest or connection to the character (Green & Brock, 2000; Hoeken et al., 2016). For example, in health research, a narrative detailing the effects of a caffeine overdose found that similarity with the protagonist (i.e. values, attitudes, and experiences) had a direct effect on character identification leading to stronger perceptions of threat severity and perceived persuasiveness of the narrative (Chen et al., 2016). In the context of sport, a narrative highlighting the threat of climate change on athletes for example could be particularly persuasive to sports fans. For instance, sport fandom has been shown to be an important factor influencing the adoption of sustainable behaviours (e.g. recycling or carpooling), due to the strong emotional connections fans have towards their clubs (Casper et al., 2014). This aligns with the idea that by framing climate change in terms of what "objects of care" it will harm or take away from us can increase risk perceptions and negative emotions, and thus prompt them to engage in pro-environmental behaviours (Keller et al., 2006; Lujala et al., 2015; Yang et al., 2015; Wang et al., 2018). Thus, sport fandom may moderate the impact of an athlete narrative on risk perceptions.

5.4 Athlete activism

There has been a recent growth in research focused on athlete activism. According to Haslett et al (2020), athlete activism refers to when athletes use their platforms to discuss or raise awareness about a cause or issue (e.g., racism, human rights, mental health, environmental issues). Existing research has contributed to knowledge in several areas such as: guidelines for coaches on how to support athlete activists (Tibbetts et al., 2017); the positive (e.g. sense of purpose) and negative consequences (e.g. public criticism) of activism (Kaufman, 2008); the history of activism in sport (Kilcline, 2017); media coverage of athlete activism (Schmidt, 2018); and fan engagement with athlete activism (Smith & Tryce, 2019; Brown et al., 2022). A study by Mihala (2019) on the role of professional skiers and snowboarders in combatting climate change shows that knowledge and experiences of climate change impacts and the concern for the future of their sports strongly motivated activist behaviour.

While there has been a significant increase in research on how the public respond to athlete activism, the research has predominantly focussed on how athletes use their sporting platforms to address social causes related to race and gender (Sappington et al., 2019). In comparison, research on how the public respond to athlete activism and the perceived credibility of athletes as advocates of environmental issues has received much less attention. However, there are a few exceptions. For example, Orr (2022) conducted a study based in the U.S. using an experimental approach to examine the perceived credibility of five professional athletes who used social media to advocate for climate action. Credibility was assessed based on agree-disagree responses for six items taken from Attari et al's (2016) credibility messengers scale. Findings revealed that overall, athletes were perceived as somewhat credible messengers on climate change. That said, critics have suggested that although athletes have sizeable platforms, they are not knowledgeable enough to form and/or voice reliable opinions about social or environmental issues, which may influence the general public's receptivity to a sport narrative (Butterworth, 2014; MacPherson & Kerr, 2021).

5.5 Research questions

The above literature review highlights the potential of narratives to improve the effectiveness of climate change communication. In particular, it shows that there is an opportunity to explore the impact that athletes can have in communicating the risks of climate change effectively. Therefore, sports practitioners should consider how to communicate the risks so

that a more diverse non-expert audience will feel that climate change is a relevant and important issue to address.

We conducted an online experiment with UK residents to empirically test whether using a sport narrative produced an impact on risk perception and emotional response to heatwaves and climate change. Analysis of the data, therefore, focused on the following research questions:

1: To what extent do the following message types – basic heatwave information, statistical information only, lay person narrative or sport narrative – affect participants' (a) heat and climate change risk perceptions and (b) emotional responses.
2: What is the effect of heatwave message type on short-term behavioural response? (i.e., requesting further heatwave information)
3: What is the effect of heatwave message type on perceived informativeness? (i.e., whether the information is considered easy to understand, convincing, interesting, relevant and trustworthy).

5.6 Methodology

An online experiment was conducted with a nationally representative UK sample stratified across three demographics: age, sex, and ethnicity. All experiments were granted ethical approval by the Research Ethics Committee of the University of Leeds (LTSEE-130) and all research was conducted in accordance with the Declaration of Helsinki. Full details of the socio-demographic characteristics, study materials and survey items can be found in Appendix C.

5.6.1 Participants

A total of 738 UK residents were recruited to obtain more than 90% power of detecting a small-medium effect (f = 0.15) in a one-way ANOVA with five groups. G*Power software was used to compute the statistical power analyses. Participants were recruited via Prolific Academic and were rewarded a small monetary reward for completing the study (£8/hr). Following recommendations for detecting inattention in online studies (Maniaci & Rogge, 2014), we excluded 25 participants who completed the study in less than half of the 5% trimmed mean completion time (5:16). The final sample obtained was composed of 354 male, 356 female and 3 other respondents (N = 713). The age of participants ranged between 18

and 84 (M = 46.8; SD = 15.75). Around 87% self-identified as white, 3% as Black/Black British/Caribbean or African, 8% as Asian or Asian British, 0.7% as mixed / multiple ethnicity and 1% as other. Approximately, 16% were educated to GCSE level, 22% had A levels, 55% had a university degree, 1% had an apprenticeship, 4% had other qualifications while 2% had no qualifications.

5.6.2 Heatwave messages

To empirically test whether using a sport narrative produced an impact on risk perception and emotional response to heatwaves and climate change, we produced four short messages (~250 words), that differed according to the type of evidence or narrative presented in a heatwave message (i.e. basic heatwave information, statistical information only, lay person narrative and sport narrative). The structure of each message was identical across conditions, with each message containing information on heatwave definition, impacts and future change. The source of the statistical information was mentioned in the message (i.e., the Met Office) but the other messages were not attributed to a specific source.

In the *basic heatwave information* condition, participants read a message containing information about heatwaves in the UK taken from the Met Office. In the *statistical information only* condition, participants read the same message coupled with statistical information. In the *lay person narrative* condition, participants read a message about the personal heatwave experience of an office worker called Sam, who describes how the 2018 heatwave affected their everyday life at home, during work and travel as well as their elderly Grandma's health. In the *sport narrative* condition, participants read a message about the personal heatwave experience of an elite marathon runner called Sam from the UK, who competed in the Tokyo 2020 Olympics. Sam describes how the heat affected the health and performance of themselves and their fellow athletes. Extracts from the messages used in each group can be found in Table 5.1 below.

Table 5.1: Extracts from each message group.

Basic heatwave information	Statistical information only
Definition: "A heatwave is defined as an uninterrupted period of exceptionally high temperatures. There's a threshold temperature for it to be described as a heatwave, and it varies from the mid to high twenties depending on which UK county you are located in". **Impacts:** "Older people and those with pre-existing health conditions such as heart disease are particularly at risk. Children and those who are less mobile may also be more vulnerable". **Future change:** As a result of climate change, hotter-than-usual days and nights are becoming more common in the UK and heat waves are expected to become more frequent, more intense and longer in duration.	**Definition:** "According to the Met Office, a UK heatwave is met when a location records a period of at least three consecutive days with daily maximum temperatures meeting or exceeding the heatwave temperature threshold. The threshold varies by UK county in the range of 25°C and 28°C". **Impacts:** "Older people (65 and over), those with pre-existing health conditions and young children are particularly at risk…According to official statistics, nearly 90% of excess deaths during the [2020] heatwave occurred in the elderly population". **Future change:** "Climate change is projected to raise average temperatures in the UK by 5°C by 2070, making the kind of temperatures seen in the mid-August heatwave of 2020 the norm for summers of the future".
Lay person narrative	**Sport narrative**
Definition: To me, a heatwave describes a period where temperatures are well above average. I first experienced such conditions during the 2018 heatwave. **Impacts:** I live in an apartment on the top floor, and everything was baking, including myself. Even sat still, I could feel myself sweating and getting more agitated. I could barely sleep. **Future change:** Since that day, I have learned that climate change is expected to make heatwaves longer, more intense and more common in the UK. This is a huge concern for me.	**Definition:** "To me, a heatwave describes a period where temperatures are well above average. I first experienced competing in such conditions during the Tokyo 2020 Olympics". **Impacts:** "During the race, I remember it getting much harder, much earlier than normal. And the times were a lot slower as well. I was feeling lethargic, dizzy and constantly dehydrated". **Future change:** "Since that day, I have learned that climate change is expected to make heatwaves longer, more intense and more common in the UK. This is a huge concern for me"

5.6.3 Measures

Climate change risk perception was measured using eight items selected from a previous study (van der Linden, 2015). Participants were asked to respond to a series of eight questions assessing the level of perceived climate change risk on a personal and global scale (e.g., "How concerned are you about climate change?" and "How serious would you estimate the impacts of climate change for the United Kingdom?"), using 7-point Likert scales (e.g., 1 = Not concerned at all, 7 = Very concerned; 1 = Not serious at all, 7 = Very serious). Responses across items were averaged to produce an overall evaluation score (Cronbach's $\alpha = 0.95$).

Heatwave risk perception was measured using 9 questions assessing three constructs related to heatwave risk perception: perceived probability of harm, perceived severity of harm, and worry or concern about the hazard. Responses across items were averaged to produce an overall evaluation score (Cronbach's $\alpha = 0.94$). These items were taken from previous research in climate change risk perception (Howe et al., 2019).

Emotional response was measured using both qualitative (open-ended questions) and quantitative items (Likert scales). Firstly, participants answered the question "using one or two words please state how you feel when you think about the issue of climate change". Secondly, the Berlin Emotional Responses to Risk Scale (Petrova et al., 2022) was used to measure discrete emotions. Participants indicated how assured, hopeful, relieved, anxious, afraid, and worried they felt on scales from 1 (not at all) to 7 (extremely). The order of the adjectives was randomized. Following Petrova et al (2022), we averaged the scores across all negative adjectives as a measure of negative affect ($\alpha = 0.94$), and across all positive adjectives as a measure of positive affect ($\alpha = 0.79$).

Perceived informativeness of message was measured using 9 items adapted from previous research in health risk communication (Bruine de Bruin et al., 2017) asking participants to indicate how convincing, easy, interesting, worrisome, useful, personally relevant, and trustworthy the information was, as well as on how much experience and evidence was the information based. Responses across items were averaged to produce an overall evaluation score (Cronbach's $\alpha = 0.90$).

Short-term behavioural response was measured using information seeking behaviour (Russell & Ashkanasy, 2021). This comprised of a question at the end of the post-test survey

where we asked participants if they would like to read additional information on heatwave risk and climate change. The responses were coded as 1 if participants requested information or 0 if they did not.

Sport Fandom was measured using the Sport Fandom Questionnaire (Wann & Pierce, 2005) which assesses the degree to which individuals identify with the role of a sports fan. This comprised of five statements (e.g., I consider myself to be a sport fan) and participants indicated their level of agreement on an 8-point Likert scale (1 = strongly disagree; 8 = strongly agree). The higher the overall total scores for the given items, indicated a higher level of sport fandom. Responses across items were averaged to produce an overall evaluation score (Cronbach's $\alpha = 0.97$).

Numeracy was measured using Schwartz et al's (1997) 3 item numeracy measure (e.g., Imagine that we flip a fair coin 1,000 times. What is your best guess about how many times the coin would come up heads in 1,000 flips?). Participant's responses were coded for accuracy.

5.6.4 Experimental procedure

To ensure that the narratives and survey questions were clear, a pilot of the main study was conducted via Prolific Academic with members of the UK public (N = 10). Results of the pilot study were used to refine the wording of the introduction and the order of a few questions in the survey (i.e., informativeness was moved to the end of the post-test survey). The experiment was administered online in May 2022.

The main study involved a pre-test, post-test design. A total of 761 completed the pre-test with 738 completing both the pre- and post-test surveys, a retention rate of 97%. Pre-test surveys without accompanying post-test surveys were omitted from the analysis. Upon providing informed consent, participants completed the pre-test study whereby they were presented with an online survey comprising of six sections (i.e., climate change risk perception, heatwave risk perception, emotional response, sport fandom, numeracy, and socio-demographics). The sections of the survey were randomized to avoid order effects. One week later, the same participants were invited to complete the post-test study. Participants were randomly assigned to one of five message groups – basic heatwave information (N =

144), statistical information only (N = 144), lay person narrative (N = 142), sport narrative (N = 146) and control respectively (i.e., no information; N = 137).

After reading the short message, participants were presented with the same survey questions as the pre-test study, with the addition of questions on perceived informativeness of the message and short-term behavioural response.

5.6.5 Analysis plan

To address our primary research question (RQ1), we conducted a multivariate analysis of covariance (MANCOVA) on heatwave and climate change risk perceptions and emotional responses (positive and negative) with message type as between subject factors. Participant's pre-test scores were used as the covariate in the analysis. For all outcomes, overall analyses yielding significant interactions were followed by ANCOVAs with a Bonferroni-adjusted post-hoc test comparing heatwave and climate change risk perceptions at each message type. To further explore the effects on emotional response, we applied sentiment analysis to sort the qualitative responses. To address our research questions about the impact of the different messages on short-term behavioural response (RQ2) and perceived informativeness (RQ3), we conducted a chi-square test and an ANOVA on these outcomes, respectively. Finally, supplementary analyses were conducted to explore whether the effects of message type on heatwave and climate change risk perceptions were moderated by numeracy or sport fandom. Moderation analyses was conducted using SPSS's PROCESS macro (Hayes, 2017) to explore the moderating effects of numeracy and sport fandom on the relationship between message type (i.e., statistical only and the sport narrative) and (1) climate change risk perceptions; and (2) heatwave risk perceptions post intervention. Model 1 was fitted as follows: message type (i.e., statistical only, sport narrative, and the control group as the baseline) was the independent variable; climate change risk perceptions was the dependent variable; and sport fandom and numeracy were the moderator variables. Model 2 followed the same set up with heatwave risk perceptions as the dependent variable. In addition, we conducted regression analyses to assess the role of participant characteristics (i.e., age, gender, political party identification, and education level) in predicting climate change and heatwave risk perceptions.

5.7 Results

Following a check of the analysis assumptions, we conducted a one-way between groups ANOVA to test for demographic differences between groups. We found no significant differences between groups for age, gender, education, political party identification, household income, ethnicity, numeracy scores or sport fandom.

The interaction between sport fandom and the sport narrative condition was not significant for climate change risk perceptions (b = .0545, SE = .1042, t (701) = .5227, p = .6014) or heatwave risk perceptions (b = -.0319, SE = .0607, t (700) = - .5263, p = .5988). Similarly, the interaction between numeracy and the statistical only condition was not significant for climate change risk perceptions (b = -1.6510, SE = 1.17, t (701) = -1.4108, p = .1588) or heatwave risk perceptions (b = .4286, SE = .8165, t (700) = .5249, p = .5998). This suggests that the relationship between message type and risk perceptions does not change based on the individual's level of numeracy or sport fandom.

The multiple regression examining the role of participant characteristics on climate change and heatwave risk perceptions revealed that older people (p = .011) and those who supported the conservative party (p = <.001) were more likely to have lower climate change risk perceptions. In addition, higher levels of educational attainment (p = .006) were shown to predict higher levels of climate change risk perceptions. The variables did not significantly predict heatwave risk perceptions (p = >.05) (Table 5.2).

Table 5.2: Predictors of climate change and heatwave risk perceptions

	Climate change risk perceptions		**Heatwave risk perceptions**	
	B	**p**	**B**	**p**
Age (in years)	**-.097**	**.011***	-.006	.871
Gender (female)	.042	.248	.024	.521
Education (higher)	**.101**	**.006****	-.015	.687
Political party (labour)	.052	.190	.000	.995
Political party (conservative)	**-.149**	**<.001*****	-.077	.070
R^2	.068		.007	

***Significant at the 0.001 level; ** significant at the 0.01 level; *significant at the 0.05 level**

The one-way MANCOVA with climate change risk perceptions, heatwave risk perceptions and emotional responses as dependent variables revealed a significant effect of message type after controlling for pre-test scores (Wilks's $\Lambda = .96$, F (16, 2133) = 1.83, $p = .023$, $\eta_p^2 = .010$). In addition, follow up ANCOVAs on the outcome variables revealed significant effects of message type on climate change risk perceptions (F (4, 701) = 2.96, $p = .019$, $\eta_p^2 = .017$) and heatwave risk perceptions (F (4, 701) = 2.71, $p = .029$, $\eta_p^2 = .015$). There is a strong positive correlation between climate change risk perceptions and heatwave risk perceptions pre and post-test ($r = .471$ / $.572$, $p = .001$), with high levels of climate change risk perception associated with high levels of heatwave risk perception. However, we found no significant effects of message type on participant's positive emotional responses (F (4, 701) = 1.28, $p = .276$, $\eta_p^2 = .007$) and negative emotional responses (F (4, 701) = .388, $p = .817$, $\eta_p^2 = .002$). Appendix C4 includes the mean and standard deviation scores for each dependent variable across each message type.

To further explore the non-significant effects on emotional response, using NVivo 12 (QSR International) we applied sentiment analysis to sort the qualitative responses into positive and negative groupings. Following Kim and Hovy (2004), the point of classification was attitude, which is the orientation of the word / phrase being positive or negative sentiment. When asked what word / words come to mind when they thought about climate change, participants responses were primarily negative in both the pre and post survey. For example, in both

surveys, the frequency of moderately / very negative sentiments expressed regarding climate change was more than double (n = 175) the positive sentiments (n = 68). The negative words used in both surveys were extremely similar and largely reflected feelings of worry and concern (t1 = 260; t2 = 284), followed by feelings of anxiety (t1 = 39; t2 = 42), sadness (t1 = 32; t2 = 35), helplessness (t1 = 27; t2 = 30), and frustration (t1 = 30; t2 = 27). The same trend was found when comparing each message type with a large majority reporting feelings of worry and concern (31%-44%). Despite reading the message on heatwaves and climate change, respondents feelings / emotions remained largely the same. Thus, further highlighting the ineffectiveness of the intervention to alter participants emotions towards climate change.

5.7.1 Climate change risk perception

Further post-hoc comparisons indicated that the participants who read the statistical information (M = 4.89) reported greater climate change risk perceptions compared to those who received no information in the control group (M = 4.76, p = .038, d = .09) (see Figure 5.1). The basic heatwave information, lay person narrative, and sport narrative interventions showed no difference in climate change risk perceptions when compared to the control, or to one another (p = ≥ .056).

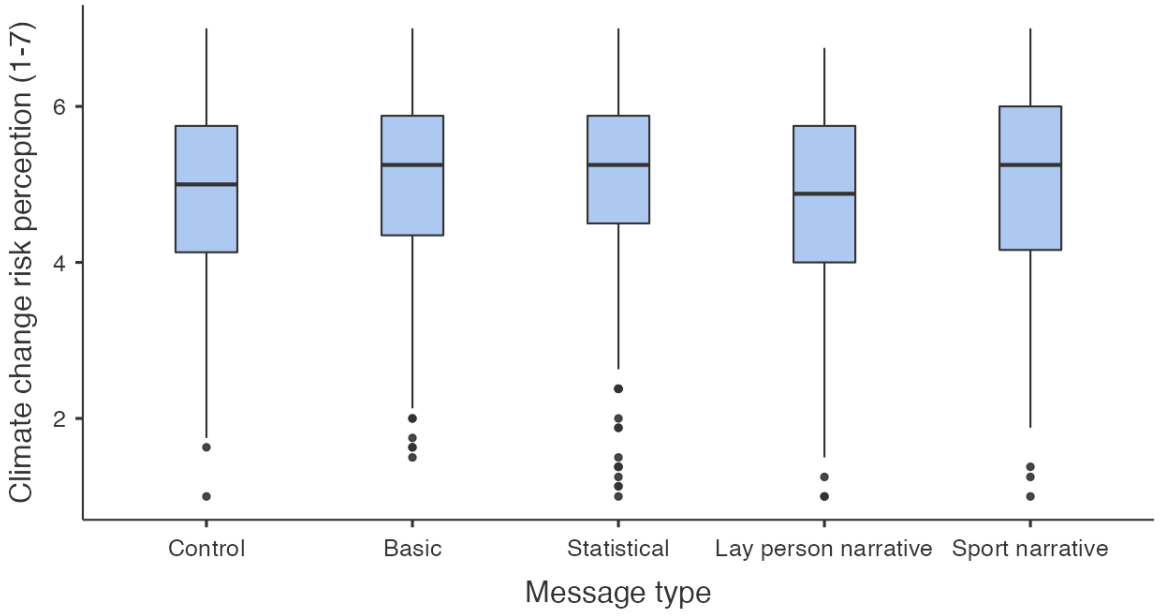

Figure 5.1: Effect of message type on climate change risk perceptions.

5.7.2 Heatwave risk perception

We also tested which message type affected participants' heatwave risk perceptions (see Figure 5.2). We found that those who read the sport narrative (M = 2.39) reported greater heatwave risk perceptions relative to those who received no information in the control group (M = 2.18, p = .008, d = .03). Contrastingly, the effect of the basic heatwave information, statistical information and lay person narrative intervention groups did not differ significantly from the control, or to one another (p = ≥ .208).

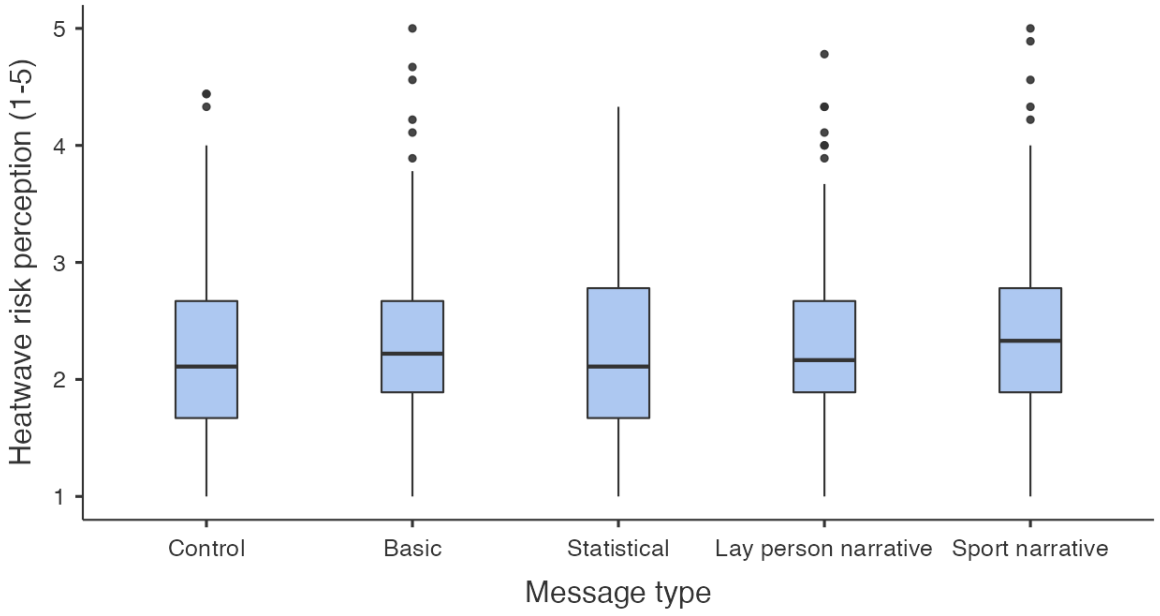

Figure 5.2: Effect of message type on heatwave risk perceptions.

5.7.3 Short-term behavioural response

The Chi-Square Test for Independence assessing the impact messages type on information requesting behaviour indicated no significant association between condition and behavioural response, $\chi 2$ (4, n = 713) = 9, p = .061. The percentage of participants in each condition group who requested further information on heatwaves and climate change were: 38.7% (control); 27.1% (basic heatwave information); 28.5% (statistical information only); 38% (lay person narrative); and 39% (sport narrative).

5.7.4 Informativeness of messages

The one-way ANOVA assessing the differences in informativeness scores across message types revealed a statistically significant difference between the 4 groups: F (3, 567) = 7.45, p = .000, η_p^2 = .04. Post-hoc comparisons indicated that those who read the basic heatwave information (M = 3.47, SD = .72) found it more informative relative to those that read the lay person narrative (M = 3.06, SD = .77, p = <.001) and the sport narrative (M = 3.18, SD = .78, p = .009). Moreover, participants in the statistical information only group (M = 3.34, SD = .84) reported greater informativeness than those in the lay person narrative group (p = .02) (see Figure 5.3). Additional moderation analyses highlighted that the effect of the statistical only message on perceived informativeness was not moderated by numeracy (b = -.0040, SE = .8103, t (571) = -.0049, p = .9961). In addition, the effect of the sport narrative on

perceived informativeness was not moderated by sports fandom (b = -.0215, SE = .0643, t (571) = -.3342, *p* = .7383)

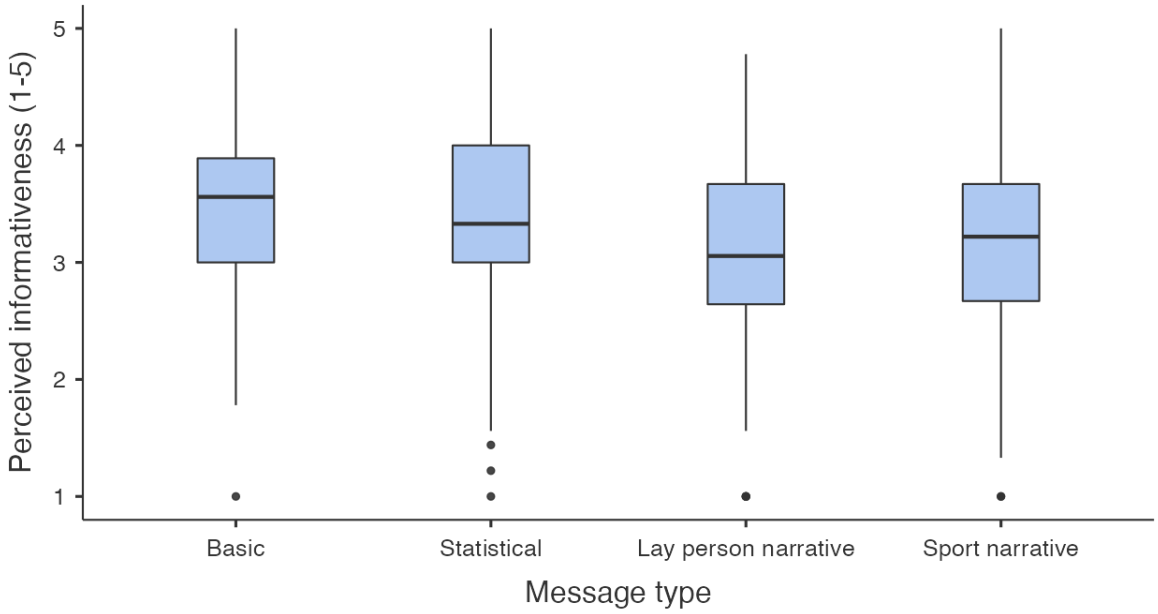

Figure 5.3: Effect of message type on perceived informativeness.

5.8 Discussion

The primary goal of this research was to empirically test whether using a sport narrative produced an impact on climate change and heatwave risk perceptions, as well as emotional responses, compared to other message types. Using an online experiment conducted among a representative sample of UK adults, we found that, relative to the control, climate change risk perceptions were significantly higher in the statistical information only group, whereas heatwave risk perceptions were significantly higher in the sport narrative group. Yet, we found no significant message type effects on participants' positive or negative emotional responses, or short-term behavioural response. In addition, individuals perceived the basic heatwave information to be more informative than both narratives, and the statistical information was perceived to be more informative when compared to the lay narrative. Further, older people and those that supported the conservative party were more likely to have lower climate change risk perceptions, whereas higher education was linked to greater climate change risk perceptions. The relationship between message type and risk perceptions did not change based on the individual's level of numeracy or sport fandom. The implications for research and practice are discussed below.

Our finding that the statistical information was associated with greater climate change risk perceptions is somewhat surprising given that the narratives vividly highlighted the potential negative effects of heatwaves and climate change whereas in the statistical information group only the consequences were mentioned. This contrasts with previous research on the persuasive effect of a narrative which shows that narratives often have a stronger influence on individuals risk perceptions compared to statistical information (Jones, 2014; Shaffer et al., 2018; Gustafson et al., 2020).

However, it is worth noting that the messages did differ in terms of source, severity, and location. To illustrate, in the statistical condition, the Met Office was named as the source of the information, and the total excess deaths in England from the heat in 2020 was included. In contrast, the narrative messages did not mention a source or include statistics on deaths linked to heat. In addition, the sport narrative described an athlete's experience in Tokyo, which is likely to be an environment less familiar to the UK participants. The inclusion of a source and varying the way that climate change messages are framed i.e., bringing attention to public health implications such as number of deaths, can affect the risk perceptions and perceived severity of various audiences (Spence & Pidgeon, 2010; Feldman and Hart, 2018; Bolsen et al., 2019). To illustrate, experimental evidence from psychology suggests that fear appeals such as those that highlight the negative consequences of climate change (i.e., number of deaths) can produce higher levels of perceived severity and promote new behaviours (Witte & Allen, 2000). For example, previous research has shown that by highlighting the potential losses that could occur without climate change mitigation, can heighten fear responses which in turn can raise perceived severity of climate change (Spence & Pidgeon, 2010).

The effectiveness of the climate change messages and perceived informativeness can also depend on the participants' perceived trustworthiness and credibility of the source (Bolsen et al., 2019; Samantray & Pin, 2019). For instance, people may pay attention not only to the message but also to the messenger in interpreting new information – it is not only the content of the message that can influence people's opinions and actions, but also the source of the information (Benegal & Scruggs, 2018). In a recent YouGov survey, it was found that 84% of the public trusted the Met Office as a provider of weather and climate information (Met Office, 2022). In addition, survey research has found that the UK public tend to trust

information about climate change provided by climate scientists and government agencies (Steentjes et al., 2020). Therefore, by including a trusted source, more severe consequences located in a more familiar environment could explain why the statistical condition was associated with higher climate change risk perceptions.

However, the empirical evidence on the impact of a message source remains mixed with a recent meta-analysis showing that messages that were not attributed to specific sources were more effective in raising climate change concerns, behavioural intentions and support for climate policy, compared to the ones from known sources such as newspapers and other media outlets (Li & Su, 2018). As such, future work could explore the role that the presence of sources linked with specific frames might have on different audiences.

Contrastingly, the narrative portraying an athlete harmed by extreme heat and climate change resulted in greater heatwave risk perceptions relative to the control group. This is the first study to explore the influence of a sport narrative on heatwave risk perceptions and therefore offers unique empirical insights and suggests that sport stories should not be discounted as an effective strategy for increasing perceptions of heat risk among the UK public. This is in line with previous research in science communication which has shown that narratives can play an important role in shaping opinion, attitudes, perceptions of risk and in some cases, behaviours (Lowe et al., 2006; Winterbottom et al., 2012; Jones, 2014; Braddock & Dillard, 2016; Shaffer et al., 2018; Gustafson et al., 2020). One possible explanation for the persuasive effect of the narrative on heatwave risk perceptions may be that emotional responses (e.g., worry and anxiety) are heightened, which have been shown to have a strong influence on personal risk perceptions and behavioural response (Slovic et al., 2007; Van Boven et al., 2010; Lu & Schuldt, 2016). However, in contrast to previous research, we did not find that emotional responses (both positive and negative) were stronger in the narrative condition compared to the statistical condition. This suggests that the persuasive effect of the narrative was caused by other factors. For example, according to the theory of narrative transportation, narratives lead to persuasion by reducing negative cognitive responses. For instance, in the context of the sport narrative, individuals could have identified with the athlete or shared a similar experience, which has been shown to increase engagement and reduce the likelihood of resistance or counterarguing (Green, 2004). As a result, people are unlikely to question a story's claims and thus their perceptions may be influenced (Green &

Brock, 2000). In addition, transportation may make a narrative experience seem more real. Personal experience of local warming can be a powerful means of forming risk perceptions about extreme weather (Krosnick et al., 2006; Howe & Leiserowitz, 2013; Zaval et al., 2014; Howe, 2018; Bruine de Bruin & Dugan, 2022) and to the extent that narratives enable immersion, they may have a greater impact than non-narrative alternatives (Green, 2004).

The exemplification theory, on the other hand suggests that events portrayed in a vivid, emotional and concrete manner will be highly accessible and have a stronger influence on risk perceptions using heuristics or mental shortcuts such as the representativeness heuristic and the availability heuristic (Gibson & Zillmann, 1994). Similar in both heuristics is that people's risk perceptions are significantly influenced by examples of events or hazards that are easily recalled. As a result, people tend to misjudge the actual frequencies or probabilities of these events (Zillmann, 2006). In relation to the sport narrative, the Tokyo 2020 summer Olympics only occurred a few years ago (i.e., 2021) and the hot and humid conditions were a popular topic in the media. Therefore, due to the recency of the event and the likely exposure to the media coverage, it is likely that individuals risk perceptions were influenced by both of these factors. For future research, it would be interesting to examine the mechanisms (e.g., psychological distance and prior experience) that are responsible for the persuasive effects of certain narrative (e.g., sport) and non-narrative (e.g., statistical) message types (Bullock et al., 2021). Interestingly, people frequently base their assessment of psychological distance on prior experiences and prior knowledge. According to Spence et al (2012), people's perceived distance of climate change is influenced by their own experiences of climate change impacts such as heatwaves. Therefore, to reconcile the differing findings of messaging on heat and climate change risk perceptions, future experimental studies could explore the potential of distance framed narratives in eliciting risk perceptions related to heatwaves and climate change. As people start to experience more heatwaves and start to adapt to the new normal temperatures, one might expect a reduced effect of messaging on heatwave risk perceptions.

The findings also highlighted that the statistical message was perceived as a more trustworthy source of information, which may be a beneficial outcome to science communicators. Social science insights have demonstrated that it is possible to convey climate science in a way that is more relatable to non-scientific audiences and makes the message easier for them to understand (Corner & Clarke, 2017; Corner et al., 2018; Kumpu, 2022). Moreover, scientists

have long understood that the messenger bears just as much weight as the information itself—if not more. Consequently, while creating risk communications, researchers need to find a way to combine the delivery of factual content that is clear and correct and based on a common platform with the use of an authentic voice to gain the audience's trust. In addition, in line with previous research (Whitmarsh, 2011; Shi et al., 2016; Bruine de Bruin & Dugan, 2022), it was found that older people and those that supported the conservative party were more likely to have lower climate change risk perceptions, whereas higher education was linked to greater climate change risk perceptions. Therefore, science communicators also need to take into account socio-demographics when designing future risk communications. However, it's worth noting that increasing risk perceptions doesn't always lead to a desirable outcome and can backfire especially among sceptical audiences. Research has shown that making a clear connection between climate change and natural hazards and amplifying messages of fear and guilt can cause resistance among those who are most sceptical of it (Weber et al., 2016; Dixon et al., 2019; Dodds, 2021). It has therefore been suggested that risk communicators should refrain from using polarising language that could lessen perceived severity and risk, and instead emphasise the effects of climate change that people may encounter in their daily lives (Dixon et al., 2019). As a result, this could encourage appropriate responses to natural hazards, as well as greater pro-environmental attitudes and increased policy support.

The findings connect research from the fields of psychology, narratology (i.e., the study of narrative and narrative structure), sport ecology and climate change communication. Thus, extending our understanding of how message framing influences risk perceptions and emotional responses to heatwaves and climate change. These findings are compatible with the theoretical perspectives that argue reducing psychological distance, building identification and transportation through narratives could be an effective strategy to communicate the impacts of climate change (Zillmann, 1999; Green & Brock, 2000). Climate change messages that enable individuals to embrace the perspective and position of another could draw one closer to climate change and as such reduce psychological distance (Swim & Bloodhart, 2015). We have shown that climate change messages framed as a sport issue can increase heatwave risk perceptions, which could open up dialogue with individuals of different cultures / values and socio-political standpoints (Scheufele, 2018; Badullovich, 2020). Thus, breaking through the barriers that could impede communication efforts to sceptical audiences.

This is a promising avenue to explore as previous research has shown that UK residents generally have positive feelings about hot summers, which tend to reduce perceptions of risk (Lefevre et al., 2015).

To the best of our knowledge, this is the first study to explore how a sport narrative may impact risk perceptions and emotional responses to heatwaves and climate change. The vast majority of previous research on message framing has predominantly emphasised the scientific, environmental and economic attributes of climate change (Wibeck, 2014; Manzo & Padfield, 2016; Brüggemann & Engesser, 2017). Nevertheless, other frames such as public health, morality/ethics and political conflict appear to be gaining more attention in recent years (Maibach et al., 2010; Myers et al., 2012; Zhou, 2016; Günay et al., 2018). Thus, the present study contributes to previous research on climate change messaging by examining how different frames may influence message impacts. That is, the present study provides information about how using statistical and non-statistical descriptions (i.e., narratives) of heatwave and climate change risk may impact the responses of message recipients. The findings suggest that when science communicators adopt a frame to describe climate change impacts, they should consider the role of sport as it is well placed to raise awareness to the consequences of climate change (i.e., heatwaves). By emphasizing appeals to both scientific findings and individuals' personal experiences, previous research in health communication has shown that a hybrid messaging approach can result in greater perceived risk (Nan et al., 2015). Thus, future research should focus on the effect of highlighting both the statistical evidence and sport narrative on risk perceptions.

5.9 Limitations

Several limitations of this study should be noted. First, the experiment measured participants' risk perceptions and emotional responses directly after message exposure. It is unlikely that peoples' opinions change immediately after reading such materials. This may have contributed to the small effect sizes we found. It might be that some time may have been needed to detect effects from some participants. The long-term effects of messages are especially important in this context, given that risk perceptions have been shown to underlie individual action on climate change, which is critical in tackling the issue (Steynor et al., 2021). Second, although the term climate change was not mentioned in the study advert, it is likely that those who were not interested in and/or concerned about the topic may not have

continued with the study once they had started it, which could lead to a biased sample. However, we tried to avoid this limitation by using a representative sample of the target population. Third, the narratives used in this study described personal heatwave experiences in a sport and lay-person context, with a specific emphasis on the implications to human health. Therefore, the findings of this study should be generalised with caution.

5.10 Conclusion

This research advances our understanding of the persuasiveness of narratives to shift risk perceptions and emotional responses in a climate change context, which may have important implications for science communicators and sport practitioners. We have highlighted the potential of statistical information and sport narratives to engage people on the risks of extreme heat and climate change. A logical next step would be to combine both message types and test the influence on perceived risk of heat and climate change. Using sport to communicate about the risks of extreme heat could potentially trigger a new way of thinking about the personal relevance of climate change impacts and may provide a powerful narrative for engaging fans and wider audiences about rising climate risks. This study is an important first step in exploring how a sport narrative could be used in climate change communication efforts. More research is needed to further test and extend this promising and exciting avenue of research.

5.11 References

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Chapter 6: Discussion, contributions, limitations, and further research

6.1 Overview

The frequency, length, and severity of extreme heat events have increased worldwide at an unprecedented rate due to climate change. Among all climate change impacts (including floods and hurricanes) extreme heat has the highest mortality rate owing to heat-related illnesses (Ebi et al., 2021). Athletes, in particular, are regarded as a high-risk group, and therefore the safety of those engaging in outdoor physical activity and sports in a hotter climate is of serious concern. Despite the sports sector having high sensitivity to climate and weather impacts, it has remained under-researched in the broader climate change adaptation literature. My thesis on sport and perceptions of climate change risk has made a clear step towards addressing this gap, as well as having non-academic impact in the sector.

There is a wealth of research into the risks of thermal stress on athlete health and performance (Miller-Rushing et al., 2012; Mohr et al., 2012; Kakamu et al., 2017; Honjo et al., 2018; Smith et al., 2018; Olya, 2019; Tipton et al., 2019; Vanos et al., 2019). However, there is a relative paucity of work that includes the perspectives and experiences of the most important stakeholders – the athletes themselves (see Scott et al., 2022 as an exception). Given the global significance of sport and the obvious vulnerability of athletes, the lack of empirical research on the effects of extreme heat and climate change in this context is surprising (Orr & Inoue, 2018). This is despite the increasing acknowledgement of the importance of personal experience of extreme weather events as a tool to influence risk perceptions related to climate change (Weber, 2006; Marx et al., 2007; Spence et al., 2011; Zaval et al., 2014; van der Linden, 2015; Demski et al., 2017). Within this thesis, I have assessed elite athletes' perceptions and experiences of extreme heat and climate change and examined to what extent these experiences can be used as narratives to influence peoples' perceptions of heat and climate change risk.

The role of personal experience was studied using a variety of techniques moving from a broad scale literature review in Chapter 3 to narrow, applied and more detailed approaches in Chapter 4 and 5. Through the three results chapters, the thesis has made several important contributions to knowledge including:

1. Highlighting the socio-psychological determinants that may influence how people interpret weather-related experiences;
2. Operationalising the concept of personal experience within the context of extreme heat and elite level sport;
3. Providing new insights into how athletes perceive, experience, and respond to extreme heat; and
4. Advancing our understanding of the potential for athletes' experiences to be used as tools for heat and climate change risk communication.

This chapter begins by summarising the findings from the three results chapters, how they fulfil the three research questions, and outlining how the three empirical chapters link together to form one cohesive piece of research. I then outline the implications of this research in relation to theory, methodology and practice, and conclude by outlining limitations and the promising avenues for future research.

6.2 Summary of findings

Each of the results chapters focussed on one of three research questions. This thesis has followed a sequential structure with each empirical chapter (Chapters 3-5) building upon and answering questions posed by the findings of the previous. This section briefly summarises the findings from each chapter in relation to the three research questions and how they interlink. The three research objectives and three studies of this thesis were as follows:

6.2.1 To critically review the literature on the interrelationships between personal experiences of local weather anomalies, extreme weather events and climate change beliefs.

Objective one was addressed in the first published paper of this thesis (Chapter 3). Utilising a narrative review approach, I reviewed 42 papers that have studied the relationship between climate change experiences, beliefs and actions; exploring how specific mechanisms help to explain how and why weather experiences may (or may not) influence people's perceptions of climate change. Overall, I found mixed evidence that weather shapes climate change beliefs. Although there is some support that local warming can generate climate change concern (see (Joireman et al., 2010; Egan & Mullin, 2012; Deryugina, 2013; Hamilton & Stampone, 2013; Shao et al., 2014, 2016; Shao, 2017), the capacity for personal experience to promote action may rely upon the experience first bring attributed to climate change (Ogunbode et al., 2019).

Specifically, this work builds and expands upon past climate experience research – primarily from the fields of psychology and climate change (e.g., Demski et al., 2017; Spence et al., 2011; Whitmarsh, 2008) that have largely examined the conceptual relationship between climate change experiences and public opinion in isolation. Viewing the research reviewed through the lens of prominent psychological theories goes beyond previous research and assesses the moderating factors that may influence how people interpret weather-related experiences, which in turn may shape risk perceptions of climate change. Specifically, it focuses on: (1) the availability heuristic; (2) experiential processing; and (3) directional motivated reasoning (see Druckman, 2015; Lujala et al., 2015; Konisky et al., 2016; Sisco et al., 2017; Ogunbode et al., 2019).

By bringing together knowledge from psychology and behavioural decision research, the review findings make a unique **theoretical contribution** by indicating that the influence of personal experience on climate change beliefs and action may not occur in a straightforward way. Instead, the strength of the relationship is likely to hinge on social-psychological determinants of climate change risk perceptions such as the recency and destructiveness of events, the specific type and nature of personal experience, as well as prior beliefs, political ideology and / or party identification (Howe & Leiserowitz, 2013). This highlights the importance of examining the role of motivational and cognitive biases to aid in the explanation of the relationship between experience, prior beliefs and climate change perceptions.

To advance research on this topic, the review highlights the need to synthesize research designs and methods to aid systematic comparisons, ideally using standardized measures. The findings demonstrate that further research is needed to explain the relationship between individual experience, prior beliefs and climate change perceptions, across a more diverse number of countries, populations and extreme weather events. Taking this into account, this review provided an overarching theoretical framework for understanding the importance of personal experience of climate change impacts and was used to inform the research questions in Chapter 4, which sought to explore perceptions, experiences, and responses to extreme heat among a subsection of the elite athlete population.

6.2.2 To understand elite athletes' perceptions, experiences, and responses to extreme heat in relation to climate change and explore the use of their platforms for climate activism.

Objective two was addressed in the second paper of this thesis (Chapter 4). The paper developed and applied a qualitative study, underpinned by the theories in psychology and behavioural decision research described in Chapter 3, to understand how elite athletes conceptualise and discuss heatwaves and climate change, as well as the implications of experience on their health, performance, and sport in general (see Chapter 4). It responds to calls from previous studies for more research addressing the relationship between personal experience and climate change risk perceptions on different populations and other forms of extreme weather such as heatwaves (Demski et al., 2017; Howe et al., 2019; Sambrook et al., 2021), as well as calls for more qualitative approaches in sport science addressing athletes' experiences and perspectives on training and competing in different environments (Bekker et al., 2020; Scott et al., 2022; Jong et al., 2023).

Firstly, this study highlighted that elite athletes lacked clarity regarding the cause, effects, and pressing need to address heatwaves and climate change. In terms of knowledge and understanding of the dangers of heatwaves, there was a definite divide, which may be explained by the type of sport, access to the most recent research, athlete level, and individual experiences with performance and health impairments. The degree of readiness among individuals and organisations was greatly impacted by these elements, together with the expectation of unusually hot weather. In addition, this research also showed that athletes were aware of the ongoing struggle that heatwaves and climate change pose for sport and future generations, with worries that further warming will adversely affect grassroots sport, participation, and human health. This was true despite the uncertainty and clear knowledge gap. In light of this, it was clear that some athletes had powerful and emotional narratives to share, with the vast majority stating their motivation to use their platforms to discuss their experiences and the wider issue of climate change with their communities. However, many were unsure on how to communicate their stories and identified a variety of enablers such as care for the environment and barriers such as knowledge and education that affected their capacity to communicate the issue to a variety of diverse audiences.

There is a well-documented relationship between extreme heat events and increased heat illness among athletes, as well as impaired physical and mental performance (Miller-Rushing

et al., 2012; Mountjoy et al., 2012; Yankelson et al., 2014). As such, a 'one -size fits all' approach to athlete health protection has been suggested and includes specific interventions such as heat acclimatisation, which is considered the most effective countermeasure to protect athlete health and optimise performance (Périard et al., 2017). However, heat acclimatisation usually takes longer than the current heatwave duration (~14 days) and therefore if the temperature and humidity levels are higher than predicted and/or prepared for, athletes could be subject to heat stress. Périard et al (2017) assessed the exertional heat illness history and preparedness in athletes competing at the World Athletics Championships in hot and humid conditions, but to the author's knowledge, no research has applied a qualitative approach to understanding the personal heat experiences of athletes.

Considering the importance of experiential processing, heuristics and motivated reasoning in driving judgments and decision making to understand the constructed nature of elite athlete experience extends behavioural decision research literature by situating the concept of personal experience within the context of extreme heat and elite level sport. The study findings make an **empirical contribution** by providing new insights into elite athletes' perspectives on / experiences of extreme heat, the factors affecting knowledge and understanding of the risks, as well as the enablers and barriers to communication. Although there are a few studies that have considered athlete perspectives of climate change impacts in other sport settings such as the Winter Olympic Games (e.g. Scott et al., 2022), the work in this thesis is the first of its kind to interview elite athletes about their perspectives and experiences of extreme heat and climate change. Specifically, the findings advance knowledge on the human dimensions of extreme heat and climate change in sport, demonstrating that elite athletes have powerful narratives to share and have unique and important insights to offer to the climate change discourse, particularly with respect to the impacts of extreme heat events, current responses and options for adaptation at different levels (e.g., individual and organisational).

6.2.3 To examine the influence of heatwave message type on risk perception about extreme heat and climate change.

Objective three was addressed in paper three (Chapter 5) of this thesis. As mentioned above, Chapter 4 highlighted that athletes have powerful narratives to share but many were unsure of how and if to communicate their stories. Therefore, using an online experiment, Chapter 5 builds on these findings and sought to examine to what extent a sport narrative could

influence risk perceptions and emotional responses related to heatwaves and climate change. The paper makes a **methodological contribution** by developing four short messages (~250 words), that differed according to the type of evidence or narrative presented in a heatwave message (i.e., basic heatwave information, statistical information only, lay person narrative and sport narrative), all of which could be further tested and adapted in future research (e.g., combining statistical and narrative messages). Relative to the control group, the statistical information only group showed significantly higher means on climate change risk perceptions, and the sport narrative group reported significantly higher heatwave risk perceptions. I found no significant message type effects on participants' positive emotional responses and negative emotional responses.

Although communication studies of this type (i.e., comparing the impact of statistical information vs narrative) have been conducted in other fields, such as health and social sciences (Lowe et al., 2006; Winterbottom et al., 2012; Jones, 2014; Braddock & Dillard, 2016; Shaffer et al., 2018), this work is the first of its kind to test the influence of an elite athlete's real life extreme heat experience on risk perceptions related to heatwaves and climate change. The study findings make an **empirical contribution** by indicating that the message highlighting was most effective in eliciting climate change risk perceptions, whereas the message highlighting an athlete's experience was most effective in eliciting heatwave risk perceptions. These findings advance our understanding of the types of evidence that could most influence risk perception in the context of heat and climate change (i.e., statistical information vs narratives), suggesting that both message types are persuasive, but may work in different ways on different outcomes. The results suggest that trust in science and the source may be relevant to explain the influential power and higher information value of the statistical evidence. For instance, climate change is usually presented in a scientific way by industry experts in the UK (i.e., the Met Office), and therefore given the established connection between statistical information and climate change, it is likely that the public give greater weight to analytic processing when aligning their risk perceptions (Weber et al., 2016; Steentjes et al., 2020).

The latter finding relating to athletes' experiences should be considered especially important, as it adds a key piece of evidence to work relating to the credibility of athletes as messengers of environmental issues (Orr, 2022). The results suggest that the theory of narrative transportation and exemplification theory may be relevant theories to explain the persuasive

power of the sport narrative, as their key components (e.g., identification, immersion, vividness, perceived representativeness and ease of recall) have been shown to be key predictors of persuasion (Gibson and Zillmann, 1994; Green 2000; Zillmann, 2006). For instance, individuals may have related to the athlete, had a comparable experience or remembered seeing or hearing about the hot conditions in Tokyo and therefore leaned on experiential processing to form risk perceptions.

Overall, we have learned that elite athletes' experiences of extreme heat are complex, and each experience is unique to the individual and potentially from other sport stakeholders such as coaches and spectators. However, these personal experiences are powerful, rich in emotion and in some cases influenced how athletes' think and feel about extreme heat and as a result shaped their actions and behaviours at future competitions in hot environments. Not only did these experiences offer a window into an alarming and escalating norm for sport events, but they also provided a unique perspective from a population where the impacts of extreme heat will be exacerbated. Further, the athletes' experiences were also shown to be influential on the UK population that has historically welcomed an impending heatwave (Finucane, 2000; Taylor et al., 2014; Lefevre et al., 2015).

By studying the elite athlete population, we have gained a wealth of knowledge about their personal experiences with extreme heat and how they respond to them. In this context, it's important to understand the psychological processes which may influence whether a heatwave experience is readily available in an athletes' mind, and how this may be similar or different to how a lay person may process the same sensory information. For instance, during the interviews, some athletes linked their experiences to sudden and unexpected events. This is an important finding as events that are viewed as out of the ordinary in comparison to expectations and prior experiences are more likely to attract greater attention and be more vividly remembered (Hunt, 2006). As such, the athletes' experiences were particularly distinctive as they were different from those they had anticipated or experienced in the past. This is consistent with research showing that attention to climate-related events is significantly predicted by the degree of abnormality or unexpectedness (Sisco et al. 2017).

In addition, extreme heat can have significant consequences to an athlete's health and performance and therefore due to the salience of health cues, these events are more likely to

be considered more important and more personally relevant. For instance, a heatwave is likely to get noticed if it has ramifications that are important or consequential to someone (Conway 2005; Tomaszczyk et al. 2008). Further, if these prior experiences are linked to intense emotions, the memory is more likely to be long-lasting, vivid and accurate. If associated with negative emotions, athletes may be more inclined to gain knowledge on the impacts of heat and start to introduce strategies that reduce the risk, whilst also maximising health and performance (Levine and Pizarro 2004). However, research has also indicated that strong negative emotions may hinder one's ability to recall information (Deffenbacher et al. 2004; Hoscheidt et al. 2013). This process of personal relevance could explain why athletes who had first-hand experience of the negative impacts of heat were more likely to take preventative and coping measures at future competitions. This process could be similarly important for lay people, especially if they consider themselves at risk of heat-related illness and therefore take more notice and more precautions when these events occur. However, not everyone experiences the effects of extreme heat equally; those with pre-existing medical issues, low incomes, elderly persons, and small children are notably more vulnerable (PHE, 2019). And in the context of the UK, even those that are considered to be vulnerable may not perceive themselves as at risk of extreme heat (Wolf et al., 2010). Therefore, it has been suggested that media storylines on extreme heat should place vulnerable people at the centre of communications in order to increase perceived risk and personal relevancy (O'Neill et al., 2023).

Lastly, some athletes before a competition spoke of having ongoing conversations about the effects of heat on their health and performance with their coaches and medical teams, as well as about how to mitigate the effects. Referring back to the psychological research, it is possible that the frequent talks about heat and its possible drawbacks raised the prominence of health cues, placing these experiences front and centre in athletes' minds and increasing the likelihood that they will be observed and recalled (Brügger et al., 2021). Research has shown that these social and societal processes such as thinking and talking about one's own experiences or being notified by media reports allows the experience to be processed at a deeper level, increasing the possibility that the information may be retrieved later (Burgess and Weaver 2003). For example, some athletes' spoke about their experiences at international competitions such as the 2019 World Athletics Championships in Doha and the 2020 Olympic Games in Tokyo. On the lead up to both of these competitions, a number of

academic papers and online media publications (Kashimura et al., 2016; Smith et al., 2016; Kakamu et al., 2017), highlighted that they were likely to be the warmest Championships and Olympic Games ever to be recorded. Therefore, the athletes' memory of the event was not only related to the direct personal experience itself but also could have been influenced by the high level of media coverage and public attention.

In the case of heatwaves in the UK, which are likely to receive widespread attention in the form of media coverage as well as discussions with peers, these social processes may make a personal experience particularly noteworthy and memorable to a lay person (Carmichael and Brulle, 2017). However, in contrast to a sport event where extreme heat is often framed in a negative way, the media in the UK tend to narrate, conceptualise and portray heatwaves in a positive manner. For example, newspapers often use images of sociable groups enjoying leisure activities, outdoor spaces as well as eating and drinking in the sunshine, often depicting heatwaves as something to enjoy. Images rarely include the negative aspects of extreme heat, and when they do the most vulnerable people are not included (O'Neill et al., 2023). As a result, a lay persons experience of a heatwave is likely to be positively skewed and therefore is likely to be different to an athletes' experience in terms of the positive affect it elicits. This is supported by the literature which has shown that individuals in the UK typically feel positive about the prospect of hot summers, which tends to lower risk perceptions (Finucane, 2000; Taylor et al., 2014; Lefevre et al., 2015). Nonetheless, the public in the UK has recently started to recognise excessive heat as a significant climate concern (Steentjes et al., 2020). Given the potential impact of athletes' experiences on heat risk perceptions, this provides a great opportunity to further explore the idea that athletes' could communicate about heat and climate risks using their personal experiences.

6.3 Theoretical contributions

According to several scholars the personal experience of extreme weather events has the potential to change beliefs, attitudes, and behaviours with regards to climate change (van der Linden, 2014; Weber, 2016). Extreme heat events present a number of issues for sport, but so far, no research has been carried out with regards to the personal heat experiences of athletes. This is despite calls for more qualitative research in athlete health protection that incorporates the athlete voice (Bekker et al., 2020), as well as further research on adaptation options to extreme heat, that is grounded in primary source data (Mallen et al., 2023; Orr et al., 2022).

Therefore, this thesis responds to the above research gaps by drawing on established psychological theories (i.e., experiential processing, heuristics, and motivated reasoning) that can account for the effects of personal experience and explain how and why they may influence opinions and actions on climate change, integrating and applying the theoretical and empirical contributions to the context of sport and climate change.

Specifically, this thesis extends behavioural decision research literature by situating the concept of personal experience within the context of extreme heat and elite level sport. The research is the first of its kind to explore the personal heat experiences in sport. Therefore, this thesis advances sport management / sport science literature and provides a new contribution to knowledge in five key ways by: (1) introducing the subjective heat experiences of athletes; (2) confirming that the scope of heat-related impacts extends to a variety of sports and competition levels; (3) identifying adaptation being implemented in sport; (4) presenting recommendations for organisational adaptation and mitigation measures; and (5) highlighting how athlete experiences may be used as tools to communicate heat risk to the general public.

6.4 Methodological contributions

I used three diverse research methods to answer the research objectives, combining qualitative in-depth approaches with robust quantitative methods. As noted above, studies on the impacts of heat on athlete health and performance have largely been driven by quantitative research questions, and often overlook the importance, value, and relevance of qualitative approaches. However, the complexities of athletes' perceptions and experiences of heat are not easily quantified and therefore researchers have called for more qualitative research that complements traditional approaches (Bekker et al., 2020; Jong et al., 2023). This thesis responded to these methodological research needs by adopting a mixed methods approach to examine personal experience within the context of extreme heat and elite level sport. For instance, the sport narrative was developed by building on the actual heat experiences that were extracted from the athletes in the interview study. These were then incorporated into the online experiment to extract new insights beyond the knowledge acquired from the separate interview study (Guetterman et al., 2015).

In addition, as mentioned above; to address the third objective I developed four messages that outlined the impacts of heat on human health. The experiment highlighted that athletes' heat

experiences were most effective in increasing heat risk perceptions, while statistical evidence was shown to be most effective in increasing risk perceptions about climate change. As such, this work has shown that statistical information and narratives may have different impacts on different outcomes (i.e., climate change vs heatwave risk perceptions), and highlights the importance of assessing climate change and heatwave risk perceptions separately in order to identify and develop effective strategies for communication. This links with recent research, which has shown that concerns about climate change and extreme weather may in fact develop in different ways (Findlater et al., 2018, 2019; Bruine de Bruin & Dugan, 2022). For instance, concerns about climate change are strongly associated with education, whereas concerns about extreme weather are more strongly associated with experience (Bruine de Bruin and Dugan, 2022). As such, research in health risk communication emphasizes the importance of considering the specific risk communication goals in each case and tailoring the information accordingly (Rowan, 1991; Rimer and Kreuter, 2006; Renn et al 2020).

6.5 Practical contributions and recommendations

It is clear from this research that to be able to implement effective heat illness prevention programs, it is vital to incorporate qualitative research methods and more importantly the athlete voice to help us understand the complexities of athlete's perceptions and experiences, including the socio-ecological context in which they occur and how best to influence those involved in athlete health protection for better and more effective practice and policies.

Previous research on sport injury prevention has highlighted that incorporating athletes' perspectives and experiences is key in shaping future education and awareness interventions (Verhagen et al., 2010; Fagher et al., 2016; Bolling et al., 2018). As such, qualitative research in sports medicine is already proving influential in policy and practice. For example, the findings of a study that reported on the experience of South African rugby players who had sustained spinal cord injuries have been utilised by the national rugby safety programme (BokSmart) to educate coaches and referees in the early recognition of these injuries (Badenhorst et al., 2018). A similar approach could be taken to address the risks of heat. International federations and national governing bodies should continue to play a key role in promoting and teaching evidence-based practice. I recommend that all stakeholders, including athletes, should regularly get updated, sport and sex specific evidence-based training materials from these organizations—not only before important championships but throughout their professional careers. Efforts ought to be designed with the ability to present

content in a variety of languages and be usable by athletes with intellectual or visual impairments.

Although there were clear obstacles to effective adoption of heatwave strategies identified by athletes in the present data, they could be partially overcome with less expensive, evidence-based substitutes for costly overseas acclimatisation camps or traditional laboratory acclimation blocks. These substitutes could include additional thermal clothing for example, as evidenced by growing data (Lundby et al., 2021). In addition, greater sharing of resources and information around heat illness between different sports and federations would ensure all athletes are optimally prepared for competition. Given the disparity between self-reported practice/knowledge and consensus-driven, gold-standard heat advice shown in the present data, athletes and their multidisciplinary support teams need instructional resources that are easily accessible and supported by the latest research.

The findings reported here suggest that athletes speaking authentically about their experience and what heat means to them and their sport could be an effective approach to heighten heatwave risk perceptions. These findings could have implications for heatwave risk communications. First, I recommend that science communicators make heatwave risk communications less complex, so that they are understandable by all audiences. Heatwave risk communications will likely be easier for people to understand if they use everyday language and (1) clearly describe heatwave impacts without jargon; (2) indicate why vulnerable populations are particularly at risk; and (3) include compelling visualisations that highlight protective action recommendations and explain why they are crucial to reduce risk (Olson et al., 2023). Second, the findings suggest that people may find it easier to relate to heatwave risk communications that reference their values or their experiences with extreme heat events. Moreover, heatwave risk communications may reach more people when they are shared during a major sport event that is impacted by extreme heat (i.e. Paris 2024 Olympics) – as evidenced by the rise in climate change-related Google searches during unusually hot weather (Lang, 2014). Current public health messages have been ineffective in increasing perceptions of risk and there is little evidence on how to communicate the dangers of such events (Howarth et al., 2019; Erens et al., 2021). Therefore, more effective communication is essential to ensure better resilience to these risks and given athletes repeated exposure to heat

and other climate impacts, sport is well placed to raise awareness to the consequences of such extreme weather events.

6.6 Non-academic contribution

In addition to the above contributions, data that were collected on athlete personal experiences of heatwaves has also been used to inform an external project called Sport 2050 – Future News, from a warmer world (Goldblatt et al., 2021). Sport 2050 was designed and developed with the intention of helping people understand the abstract long-term effects of climate change by examining potential effects on their daily life. This project, therefore, provided a perfect opportunity to engage readers who might not have otherwise been interested in learning about climate change science. For this project, I worked with the BBC Sport sustainability team, a small panel of academics and industry experts (e.g., Met Office), to create stories illustrating the challenges that different sports might face in the future. More specifically, I provided the scientific context for a story that imagined test cricket in Australia being played inside a bio-dome due to extreme heat, humidity and wildfires. In addition, based on the reviewed sport science literature, I wrote a script for an animation that explained how extreme heat affects athletes. Not only did this project highlight the impact of future climate change on sport in an impactful and creative way, but it also presented adaptation and mitigation options that informed and inspired conversation on the topic.

6.7 Limitations

Although the methodological approach taken for this thesis has facilitated the collection and analysis of a rich set of empirical data and the emergence of a number of interesting and novel insights, a few limitations are important to acknowledge.

6.7.1 Definition of personal experience

This thesis focussed on the concept of ‘personal experience’, in relation to extreme weather events such as heatwaves. Participants in the interview study (Chapter 4) were eligible for the research if they reported having trained and/or competed in extreme heat conditions. Thus, without a clear conceptualisation and definition of experience or extreme heat, individuals were left to judge for themselves what might constitute an experience of such weather phenomena. However, there is no unified definition of heatwaves internationally and therefore the term can mean different things for different people, largely dependent on location and social / cultural factors. Not only did this thesis rely on individuals’ own

interpretation of these key concepts, but also on their memories and perceptions of past events in order to describe their experiences.

In an effort to overcome this and to draw out each individual experience, I adopted several qualitative interview techniques such as active listening and probing. Firstly, I began with chatting to break the ice and establish rapport, trust and common ground early in interview. For example, I shared my background and reasons for my interest in the subject area, and I reiterated the purpose of the study, the consent process and the structure / schedule of the interview (DeJonckheere & Vaughn, 2019). I also recognised the potential for a power dynamic between the interviewer and interviewee, and therefore to help ease any discomfort I explained the significance of the participant's involvement in the study and how I was there to learn from them and deepen my understanding of the topic (Josselson, 2013). During the interview, I maintained a warm and conversational tone and avoided using jargon or slang. I also used non-verbal cues such as silence, nods and smiles to encourage further elaboration, as well as showing the interviewee I was actively listening and engaged with the conversation (Anderson & Kirkpatrick, 2016). In addition, to elicit sufficient detail, I used different probing techniques such as echoing the interviewees response, verbal agreement, and asking for expansion / further explanation using key phrases such as tell me more, can you describe and tell me what you mean etc. (DeJonckheere & Vaughn, 2019).

6.7.2 Impact of recent events on findings

Heatwaves are becoming more frequent, more intense, and longer in duration as a result of climate change (IPCC, 2023). Over the course of data collection (i.e., semi-structured interviews were collected in August 2020 to June 2021 and the experiment was conducted in May 2022), a number of events have occurred that are likely to affect its findings: the UK has experienced a series of unusually hot summers and in 2022 saw unprecedented high temperatures, exceeding 40°C in some parts of the country, the IPCC released the sixth assessment report bringing together the latest advances in climate science, the Extinction Rebellion and Just Stop Oil movements have gained momentum, and a series of major heatwaves and wildfires have occurred worldwide (Hinks and Rödder, 2023; McLoughlin et al., 2023; IPCC, 2023). Aside from a changing climate, the world has recently experienced the prolonged and devastating Covid-19 pandemic, a major land war has broken out in Europe, and the UK is currently experiencing an acute cost of living crisis that significantly raised energy prices during the winter and is now also affecting food prices, collectively

creating a unique context in which to ask people about heatwaves and climate change (Lawson, 2023). A recent survey conducted in May 2023 (Harcourt et al., 2023), suggests a shift in perceptions among the British public towards greater concern for more immediate issues such as inflation with climate change only highlighted as the fifth most important issue. However, there is also a notable increase in risk perceptions in relation to heatwaves for impacts associated with health. Consequently, the study of personal experience and risk perception is an ongoing process.

Due to time constraints, the thesis offers only a snapshot of both athletes' personal experiences and public risk perceptions in a constantly changing and evolving climate. While both of these are extremely important perspectives to add to the sport science literature, the picture is only partial and highly influenced by individuals' interpretations and different / shifting baselines (i.e., redefinition of 'normal' temperatures by each generation) (Jackson et al., 2011). However, the thesis also provides a baseline that can be measured against in future years, and therefore provides a great opportunity to continue and expand this programme of work. A follow up of this thesis, therefore, would be to repeat the analysis with a broad pool of participants to see how personal experience of heatwaves has and does develop overtime.

6.7.3 Consideration of other sports

This thesis aimed to provide a comprehensive account of athletes' personal experiences of heatwaves and current perceptions of risk and did so by recruiting fourteen elite athletes from a broad range of different outdoor sports, but the pool wasn't exhaustive. Heat stress from the environment not only affects outdoor sports (e.g., athletics, cycling, rugby), but also those who train and compete indoors in poorly air-conditioned, overheated sports halls (Schneider & Mücke, 2021). It is therefore important to note that playing a sport indoors doesn't necessarily equal protection from the adverse consequences of extreme heat. As such, there are several other sports (i.e., tennis and triathlon etc.), genders, levels (e.g., recreational; see Shendell et al., 2010), nationalities, races and ethnicities to represent, which would potentially create at least some alterations to the findings presented here. Nevertheless, this is arguably one of its strengths as the findings detailed here provide a baseline with a variety of new ideas and promising avenues for future research.

6.8 Future research directions

Throughout this thesis, several empirical insights have been highlighted, as well as potential research questions and gaps, which future research could explore and build on. For example, deeper and wider research on experiences of heatwaves and perceptions of climate change in a sport context is suggested.

6.8.1 Sport-specific case studies

In terms of wider research, studies on how elite athletes conceptualise and experience heatwaves and climate change are generally lacking. Many sport-specific case studies with the same research methodology are required to provide a more in-depth knowledge of perceptions and personal experiences of heatwaves in a sport context. It is insufficient to generalise the thesis findings with only one study, although the interviews provided meaningful and valuable insights. What is missing from this PhD is engagement with a broader pool of athletes. Previous research has shown that there may be variations in thermal responses and perspectives on heat strategies between genders, nationalities, and sports (Alabdulwahed et al., 2022; Galan-Lopez et al., 2023). For example, female athlete populations have demonstrated sub-optimal practices compared to males which may be due to lack of knowledge (Notley et al., 2021). In addition, athletes from cold/ temperate climates have been shown to be less likely to adopt heat strategies due to actual and/or perceived barriers faced accessing facilities and hot environments to live/train (Esh et al., 2024). Due to these individual differences, it is imperative that further survey research is conducted on large competition samples across the sporting landscape to determine how elite athletes outside of the specific events included in this PhD prepare to compete in the heat. This key information would allow stakeholders to deliver evidence-informed policy, education and event-planning related to competitions whilst helping athletes overcome barriers they may experience (e.g., access to facilities and expertise). In addition, by clarifying common perceptions and experiences, the context-specific factors of each sport will also be clearly revealed. Then, solutions for sport-specific issues can be suggested in a more concrete and practical manner.

6.8.2 Need for longitudinal research

With climate change, extreme heat events will become more frequent, more intense and longer in duration (Dosio et al., 2018). As such, there is a pressing need to review current heat policies in sport to protect athletes, umpires and spectators from the risks of extreme heat. This is particularly important as previous research has highlighted that there can be

considerable variation in the content (e.g., parameters measured, thresholds used, key interventions recommended) and quality of the information documented (Chalmers et al., 2020). Therefore, a content analysis of EHI-related policy documents published by sport organisations should be conducted to assess the extent and quality of the evidence in relation to the most recent international best practise guidelines (Gamage et al., 2020; Racinais et al., 2023).

In addition, since the level of environmental heat stress will inevitably rise in the coming years, more longitudinal research is needed that assesses how athletes' health and performance are impacted by extreme heat in different socio-ecological contexts. Further, it has been shown that a single experience of extreme heat may not change one's attitudes and behaviours and therefore in order to examine the conditions under which athletes incorporate heat related measures, it is critical to observe the population over time. For instance, by surveying the same participants, it would be possible to examine how athletes' experiences, risk perceptions, and behaviours may change over time, as well as the effectiveness of particular policies and interventions. Without such research, it is impossible to develop such informed and reflexive sport-specific heat policies. In order to measure the effectiveness of such policies or interventions, researchers could observe and survey the same athletes for the next five years for example, which would allow data to be collected at the next two summer Olympic Games; both of which are likely to be held in excessive heat conditions (i.e., Paris 2024 and Los Angeles 2028). The experiences and lessons learnt from addressing environmental impacts at one event could serve as a valuable foundation of knowledge for future sporting events worldwide. Continued efforts to bridge the gap between research and practice in sports health and safety is therefore important.

6.8.3 Inclusion of other stakeholder perspectives and extreme weather events

As mentioned above, elite athletes experiences of extreme heat will be exacerbated and therefore are likely to be different from other sport stakeholders given how detrimental heat events could be to their health and performance. However, spectators, volunteers, practitioners, and a myriad of other stakeholders will still face environmental challenges in some way, and these will require both individual and organiser-led strategies to limit the negative effects. Therefore, future research could further develop the work in this thesis by interviewing other sport practitioners such as coaches and medical teams, as well as others attending the event such as organisers, spectators, volunteers, and workers in order to achieve

a more comprehensive picture of heatwave perspectives and experiences. In particular, sport practitioners have an instrumental role in knowledge translation and adoption of heat mitigation strategies, and thus assessing their knowledge and where they obtain their knowledge would provide invaluable insights to the results seen in athletes. Including their perspectives and experiences could lead to more well-informed discussions around heatwave adaptation and mitigation, which could be applied to developing sport specific heat policies. As discussed in Chapter 4, the methodological approach of this thesis could also be used to study other forms of climate impacts (i.e. fast-onset, slow-onset such as flooding and drought) in national contexts to build on the basis of knowledge on adaptations in sport for extreme heat. Such studies would benefit from a bigger and more interdisciplinary research team than was possible within this thesis in order to capture a more comprehensive view of how climate change is impacting sport.

Lastly, further research can build on this work by investigating the process and circumstances through which (sport) narratives can influence risk perceptions. For example, experimental studies could manipulate character identification through socio-demographic matching (Chen et al., 2016) or processing fluency (i.e., how easily the brain processes and understands messages) by mixing message audio recordings with white noise (Bullock et al., 2021). Future work could also test systematically the impact of specific characteristics of sport narratives (e.g. the context and structure of the message, as well as the type of experience described etc.).

6.9 Conclusion

This thesis sought to explore how elite athletes' experience extreme heat and highlight the influence of these experiences as tools to communicate the risks of heat and climate change. Drawing on established psychological theories, the findings presented highlights that elite athletes have powerful personal experiences to share and have unique and important insights to offer to the climate change discourse, particularly with respect to the impacts of extreme heat on health and performance, current responses and options for adaptation at different sporting levels (e.g., individual and organisational). Moreover, testing the influence of these real-life experiences and statistical evidence on climate change and heatwave risk perceptions highlights that both message types are important for future communication strategies but may function differently in persuasion. For instance, by humanising a heatwave narrative and

making a connection to athletes and sport may be a promising strategy to reach a different audience and potentially increase the UK public's perceptions of heat risk. There are calls for sport organisations to incorporate athletes lived experiences into future health protection interventions. This thesis highlights that by taking a truly athlete-centred approach will put sport in a better position to provide optimal care resulting in better protection against heat-related illnesses and injuries. Lastly, this thesis offers promising avenues for future research. With these contributions in mind, it is expected that this thesis will help raise awareness to the significance of athlete's personal experience of extreme heat and potentially the importance of these experiences as a tool to communicate the risks of extreme heat.

6.10 References

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Appendix A: for Chapter 3

Appendix A1: Characteristics of the studies reviewed and main results.

Citation	Location	Sample size	Methodology	Variables of interest	Summary of results
Akerlof et al, 2013	United States	n = 765	Observational survey data	Perceived personal experience of global warming (IV) Perceptions of global warming risk (DV) Control variables: (1) gender; (2) age; (3) education; (4) income; (5) political affiliation; and (6) cultural worldviews.	In Algar County, Michigan, perceived personal experience of global warming was associated with heightened global warming risk perceptions.
Bergquist et al, 2019	United States	n = 209	Longitudinal survey data (September, 2017)	Personal experience of extreme weather event (IV) Climate change beliefs; Intentions to act (DVs) Control variables: (1) gender; (2) age; (3) environmental concern; (4) political preferences; and (5) subjective income.	Experiencing hurricane Irma was associated with stronger negative emotions toward climate change, increased certainty the hurricane was caused by climate change and increased willingness to pay higher taxes.
Brody et al, 2008	United States	n = 512	Observational survey data	Climate change risk perception (DV)	Past local temperature changes (i.e. number of warmer-than-average days per year from 1948

			coupled with climate data	Physical variables: (1) distance to coast; (2) relative elevation; (3) sea level rise; (4) floodplain; (5) temperature trend; (6) economic damage; (7) injuries and fatalities from natural hazards; (8) property damage; (9) fires; (10) state CO_2 emission and per capita CO_2 Control variables: (1) ecological values; (2) knowledge; (3) perceived efficacy; (4) network interest; (5) education; (6) income; and (7) gender	to 2005) did not significantly influence climate change risk perceptions.
Brooks et al, 2014	United States	Survey 1 (2004), n = 1093 Survey 2 (2007), n = 832	Observational survey data coupled with weather data	Deviation from normal temperature (IV) Degree of concern about global warming and climate change (DV) Control variables: (1) education; (2) income; (3) political party; (4) political ideology; (5)	Deviation from mean temperature on the date of the survey was significantly associated with higher levels of climate change concern.

				gender; (6) age; (7) knowledge; and (8) economic concern.	
Broomell et al, 2017	United States	n = 207	Experimental - two framing conditions labelled weather (interpreting a temperature as abnormal weather) and climate (interpreting a temperature as evidence of GW).	Beliefs about global warming (IV) Perceptions of temperature (DV) Control variables: (1) age; (2) education; (3) knowledge about causes of global warming; and (4) political ideology.	In a randomized experiment, participants were aware when temperatures were abnormally hot, but classify less extreme abnormalities differently based on their beliefs in global warming.
Brulle et al, 2012	United States	n = 84,086 (data from 74 separate surveys conducted from 2002 – 2010)	Observational survey data	Extreme weather events; scientific information; mass media coverage; media advocacy; elite cues (IVs) Public concern over global climate change (DV) Control variables: (1) unemployment rate; (2) gross domestic product; (3) war deaths in Iraq and	Elite cues and structural economic factors had the largest effect on the level of public concern about climate change. Weather extremes have no effect on aggregate public opinion. While media coverage exerts an important influence, this coverage is itself largely a function of elite cues and economic factors. Promulgation of scientific information to the public on climate change has a minimal effect.

				Afghanistan; and (4) price of oil.	
Carlton et al, 2016	United States	Survey 1 (2012), n = 7836 Survey 2 (2013), n = 5478	Observational survey data	Drought severity; drought beliefs (IVs) Climate change beliefs; risk perceptions; attitudes towards adaptation (DV) Control variables: (1) age; (2) gender	Neither climate change beliefs nor attitudes toward adaptation changed significantly as a result of the drought. Risk perceptions did change, however, with advisors becoming more concerned about risks from drought and pests and less concerned about risks related to flooding and ponding. Though increased risk perceptions were significantly associated with more favourable adaptation attitudes, the effects were not large enough to cause an overall shift to more favourable attitudes toward adaptation.
Carmichael and Brulle, 2017	United States	n = 84086	Observational survey data	Availability of scientific information; extreme weather events; political disclosure (IVs) Climate change threat index (DV) Intermediary variables: (1) Mass media coverage Control variables: (1) unemployment rate; (2) gross domestic product.	Weather events had relatively small effects on climate change concern. Only extreme drought conditions significantly increased public concern about climate change.

Dai et al, 2015	China	n = 1054	Observational survey data	Perceived experiences with extreme weather events; physical or financial damages due to extreme weather events (IVs) Global climate change beliefs (DV) Control variables: (1) education; (2) gender; (3) age; (4) income; and (5) number of children in the household	Perceived experiences with several extreme weather events (particularly heatwaves) in five Chinese cities were strongly associated with climate change beliefs. Physical or financial damages due to these events lead to even stronger relationships.
Demski et al, 2017	United Kingdom	Respondents who reported direct flooding impacts (n = 162) were compared with a nationally representative sample (n = 975).	Observational survey data	Direct and indirect effects of flood experience (IV) Mitigation intentions and policy support (DV) Mediators: (1) negative emotions; (2) climate change concern; and (3) personal issue salience.	Direct experience of flooding lead to greater perceived personal vulnerability and risk perceptions of climate change, and support for mitigation and adaptation policies.
Deryugina, 2013	United States	n = 7847	Longitudinal survey data (2003-2010)	Short-term temperature fluctuations; long-term	Short term temperature fluctuations (1 day – 2 weeks) had no effect on global warming beliefs. However, longer periods of abnormally warm or cold temperatures (1 month – 1 year)

				temperature fluctuations (IVs) Global warming beliefs (DV)	did predict global warming beliefs. Only respondents with a conservative political ideology were affected by temperature abnormalities.
Egan and Mullin, 2012	United States	n = 6508	Observational survey data coupled with weather data	Short-term temperature fluctuations (IV) Global warming beliefs (DV)	Short term temperature fluctuations that occurred 1 week prior to interview were associated with climate change beliefs. However, the effect decayed quickly and did not induce permanent attitude change.
Goebbert et al, 2012	United States	n = 7968	Observational survey data coupled with climate data	Local weather change; individual-level characteristics; political ideology and culture (IVs) Perception of local weather change (DV)	Actual temperature fluctuations were a weak predictor of perceptions of local temperature change, but better predictors of perceived droughts and flooding. Beliefs about changes in local temperature were more heavily politicized than beliefs about local precipitation patterns.
Hamilton et al, 2015	United States	n = > 28000	Observational survey data	Predictors: (1) age; (2) gender; (3) education; and (4) political party. Climate change beliefs (DV)	Political identity significantly predicts individual's climate change beliefs. Acceptance of climate change rises with education among Democrats and Independents, but not so among Republicans.
Hamilton and Stampone, 2013	New Hampshire, United States	n = 5000	Observational survey data coupled with weather data	Temperature anomalies; age; gender; education; political identity; self-assessed understanding (IVs) Climate change beliefs (DV)	Climate change beliefs were predicted by temperature anomalies on the interview day and the previous day. Temperature effects were concentrated among those who identified as political independents.

Hart and Nisbet, 2012	New York, United States	n = 240	Experimental – two stimulus conditions exposing participants to news stories about possible climate change health impacts on different groups (vs. control condition)	Climate change beliefs (IV) Support for government action on climate mitigation (DV) Moderator: Political partisanship Mediator: Social identification with potential victims Control variables: (1) age; (2) gender; and (3) level of education	Embedded social identity cues interacted with political orientations to amplify public polarization on climate change. Knowledge and beliefs about climate change were not associated with support for climate mitigation policies.
Howe, 2018	Norway	n = 9669	Observational survey data coupled with seasonal climate data	Climate change beliefs; spatial climate data (IV) Predictors: (1) age; (2) gender; (3) education; and (4) political orientation Perceptions of local weather (DV)	Respondent's perceptions were sensitive to observed differences in both temperature and precipitation. Climate change beliefs had a significant effect on perceptions of seasonal temperature, but smaller effects on perceptions of seasonal precipitation.
Howe and Leiserowitz, 2013	United States	n = 1010	Observational survey data coupled with climate data	Predictors: (1) climate change beliefs; (2) age; (3) education; (4) ethnicity; and (5) political party	Subjective experiences of seasonal average temperature and precipitation during the previous winter and summer were related to recorded weather conditions and beliefs about global warming.

				Perceived personal experience of local weather anomalies (DV)	
Joireman et al, 2010	North-western United States	Study 1, n=93 Study 2, n = 42 Study 3, n = 159	Study 1: Observational survey data Study 2: Experimental - priming of words related to heat (vs. control condition) Study 3: Observational survey data	Outdoor temperature; anchoring regarding the amount of temperature increase expected in the future (IVs) Belief in global warming; willingness to pay to reduce global warming (DV) Control variables: (1) environmental values; (2) political party	Study 1: Significant positive correlation between the outdoor temperature and beliefs in global warming. Study 2: People were more likely to believe in global warming when they had first been primed with heat-related cognitions. Study 3: People were more likely to believe in global warming and more willing to pay to reduce global warming when they had first been exposed to a high vs. a low anchor for future increases in temperature.
Konisky et al, 2016	United States	n = >130000	Observational survey data coupled with extreme weather events data	Extreme weather episodes (IV) Climate change beliefs (DV) Control variables: (1) age; (2) gender; (3) minority; (4) marital status; (5) income; (6) education; and (7) church attendance	There was a positive relationship between experience of extreme weather activity and expressions of concern about climate change. However, the effect of extreme weather on public concern was only significant for recent weather events.

Krosnick et al, 2006	United States	Study 1 (n = 1413) Study 2 (n = 758).	Observational survey data	Perceived personal experience of global warming (IV) Climate change beliefs (DV)	Respondents who believed they had witnessed rising temperatures in recent years were more likely to believe in the existence of global warming.
Leiserowitz, 2006	United States	n = 673	Observational survey data	Holistic affect and affective imagery; values; sociodemographics (IVs) Global warming risk perception; climate change policy preferences; climate tax policy preferences (DVs) Control variables: (1) gender; (2) age; (3) income; (4) educational attainment; (5) race or ethnicity; (6) main source of news; (7) party identification; (8) political ideology; and (9) voter registration	Risk perceptions and policy support were strongly influenced by experiential factors, including affect, imagery, and values. Public responses to climate change were influenced by both psychological and socio-cultural factors.
Li et al, 2011	United States & Australia	Study 1 (n = 582) Study 2 (n = 251)	Observational survey data	Perceived local weather change (IV)	Respondents who thought the day they were surveyed was warmer than usual believed more in and had greater concern about global warming than did respondents who thought the

				Global warming concern and beliefs (DV)	day was colder than usual. Respondents also donated more money to a global-warming charity if they thought the day seemed warmer than usual.
Lujala et al, 2015	Norway	n = 1334	Observational survey data	Direct personal experience of climate-related hazard (IV) Climate change perceptions (DV) Control variables: (1) age; (2) gender; (3) education; (4) income; and (5) political orientation	Respondents who reported direct personal experience of damage due to a natural-hazard event were more likely to be concerned about the personal consequences of climate change. However, this direct experience did not affect their likelihood of listing climate change as a major threat for the future.
Marlon et al, 2019	Florida, United States	n = 1046	Observational survey data coupled with weather data	Predictors: (1) subjective local weather change; (2) subjective hurricane experience; (3) climate change beliefs; (4) gender; (5) political ideology; and (6) outdoor professions. Climate change risk perceptions (DV)	Floridians were unable to detect five-year increases in temperature but could detect changes in precipitation. Climate change risk perceptions were more strongly predicted by subjective experiences of environmental change, personal beliefs about climate change, and political ideology, compared to local weather variables.
McCright et al, 2014	United States	n = 1020	Observational survey data coupled with weather data	Predictors: (1) political ideology; (2) party identification; (3) education; (4) gender; and (5) age. Mediators: (1) perceived scientific	Temperature anomalies influence perceived warming but not attribution of such warmer-than-usual winter temperatures to global warming. Rather, the latter is influenced more by perceived scientific agreement; beliefs about the current onset, human cause, threat and

				agreement; and (2) global warming beliefs. Perceived local winter warming; Global warming as the main cause (DVs)	seriousness of global warming; and political orientation.
Myers et al, 2013	United States	n = 3200	Longitudinal survey data (2008 & 2011)	Personal experience Belief certainty Control variables: (1) gender; (2) education; (3) income; and (4) political ideology	Perceived personal experience of global warming led to increased belief certainty. At the same time, high belief certainty influenced perceptions of personal experience.
Ngo et al, 2020	Vietnam	n =1086	Observational survey data	Individual knowledge; Flood experience; Community participation (IVs) Perceived vulnerability; Perceived severity; Perceived adaptive capacity; Intention to take actions for reducing flood risks (DVs) Control variables: (1) age; (2) gender; (3) education; (4) income; and (5) poverty status	Significant association of flood and climate change risk perceptions with individual's flood experience, climate change knowledge, frequency of community participation and socio-demographic factors. Flood experience was the most influential driver of flood-related risk perceptions but weak for climate change-related risk perceptions and behavioural intentions.

Ogunbode et al, 2019	United Kingdom	n = 1997	Observational survey data	Predictors: (1) flooding experience; (2) climate change beliefs; (3) political affiliation; and (4) perceived normative cues Moderator: subjective attribution Perceived threat from climate change; mitigation intentions or policy support (DVs)	Personal experience of a flooding event directly predicted perceived threat from climate change, and indirectly predicted climate change mitigation responses, among individuals who subjectively attributed the floods to climate change.
Palm et al, 2017	United States	n = 9500	Longitudinal survey data (2010-2014)	Predictors: (1) experience with weather anomalies; (2) party identification; (3) education; (4) age; (5) gender; and (6) ethnicity Climate change opinion (DV)	Democrats strongly believed that climate change is occurring, and that immediate action is required. Republicans, on the other hand, generally remained convinced that climate change is not occurring or that its seriousness is exaggerated. Direct experience with warmer weather, droughts, and weather-related natural disasters had little effect on climate change opinions.
Reser et al, 2012	Australia and United Kingdom	n = 3096 (Australian sample) n = 1822 (UK sample)	Observational survey data	Direct experience (IV) Climate change concern & beliefs; risk perception; willingness to act; climate change	Prior direct experience with extreme weather events and natural disasters for Australian respondents showed consistent but modest positive relationships with climate change-related psychological variables such as belief, concern, psychological adaptation, psychological distress, and behavioural engagement.

				distress; psychological adaptation to climate change; previous exposure with natural disasters; self-efficacy (DVs)	
Shao, 2016	United States	n = 1052	Observational survey data coupled with weather and climate data	Predictors: (1) age; (2) gender; (3) income; (4) education; (5) religion; (6) ethnicity; (7) political predisposition; (8) local weather; and (9) extreme weather events. Local weather change; risk perceptions of global warming impacts; global warming priority (DVs)	Pre-existing beliefs about global warming played a dominant role in determining perceptions of weather. Respondents who believed global warming is causing an immediate impact, is serious, and needs to be a priority, motivated by their pre-existing beliefs, were much more likely to perceive the 'evidence' of global warming.
Shao, 2017	United States	n = 5916	Observational survey data coupled with weather and climate data	Political predisposition; religion; attentiveness to news sources; weather & climate (IVs) Belief in global warming existence; perception of global warming cause; evaluation of global	Warming winters coupled with cooling springs over the past 10 years had positive effects on belief in the existence of global warming. Republicans and political conservatives were less likely than Democrats and political liberals to perceive temperature rise, to attribute temperature rise to human cause, and to view global warming negatively.

				warming impact (DVs) Control variables: (1) age; (2) race; (3) family income; (4) education; and (5) gender	
Shao et al, 2016	United States	n = 2001	Observational survey data coupled with weather and climate data	Local weather and climate; attitudes towards scientists and science; political predispositions; information environment; religious beliefs and attachments; race; gender; income; and age (IVs) Perceptions about global warming (DV)	Individuals who have experienced long-term warming of summer temperatures coupled with long-term cooling of spring temperatures were significantly more likely to perceive that global warming exists and is due to human activity.
Shao and Goidel, 2016	Gulf Coast, United States	n = 3856	Observational survey data coupled with weather and climate data	Age; education; income; race and ethnicity; gender; political predisposition; attentiveness to information about climate change; and objective environmental conditions (IVs)	Political orientations rather than local conditions drove perceptions of local weather conditions. Republicans were less likely than Democrats to perceive increasing air temperatures, hurricanes, droughts, and flooding. Local weather perceptions were found to influence climate change attitudes.

				Perceptions of weather conditions; Perceptions of climate change (DVs)	
Shao et al, 2014	United States	n = varies from 287 - 1604	Observational survey data coupled with climate data	Age; education; income; gender; race; religious services attendance; political orientation; weather and climate trends (IVs) Perceptions of global warming (DV)	Local climate conditions represented by summer temperature trends over a 10-yr time period had a discernible effects on attitudes relating to the immediacy and severity of global warming.
Sisco et al, 2017	United States	10748 weather events (2011-2014) Attention measured using ~1.7 million Twitter messages	Social media data coupled with extreme weather events data and daily weather records	Extreme weather experience (type, financial damage, deaths and abnormality); absolute vs. relative levels of weather variables (temperature, wind speed and precipitation) (IV) Attention to climate change (DV)	The effects of extreme weather experiences were larger directly after weather events occurred compared to directly before. Financial damage associated with the weather events had a positive and significant effect on attention, although the effect was small.
Spence et al, 2011	United Kingdom	n = 1822	Observational survey data	Flooding experience (IV) Perceptions of climate change; behavioural intentions (DV)	Those who reported direct flooding experience expressed more concern over climate change. Increased concern about climate change was associated with greater willingness to save energy to mitigate climate change.

				Control variables: (1) age; (2) gender; and (3) social grade	
Taylor et al, 2014	United Kingdom	n = 1848	Observational survey data	Beliefs regarding changes in weather; Personal experience of specific weather-related hazards (IVs) Climate change beliefs (DV) Control variables: (1) environmental values; (2) age; (3) gender; and (4) education	Heatwaves and hot summers were perceived to have become less common during respondents lifetimes, while flooding, periods of heavy rainfall, coastal erosions and mild winters were perceived to have increased in frequency. Climate change beliefs were positively associated with hot and wet-weather-related events.
Whitmarsh, 2008	South of England, United Kingdom	Semi structured interviews (n = 24) Survey (n = 589)	Observational survey data	Air pollution affected health; experience of flooding in last 5 years; gender; age; annual income; education; political party; newspaper regularly read; and member of environmental organisation (IVs) Perceived threat from climate change; climate change considered personally very important; belief that anthropogenic	Direct experience of flooding had very little effect on respondents understanding of and responses to climate change. Experience of air pollution significantly affected perceptions of and behavioural responses to climate change.

				climate change is real; action taken out of concern for climate change (DVs)	
Zanocco et al, 2018	Laurel County, Kentucky, and Winston County, Mississippi; Yavapai County, Arizona, and Lake County, California, United States	n = 489	Observational survey data	Event proximity; reported personal harm; gender; education; income; age; political ideology and race/ethnicity (IVs) Climate change views after extreme weather event (DV)	Reported personal and community harm aligned with event proximity and larger community damages. Climate change views were strongly predicted by political ideology.
Zaval et al, 2014	United States	n = 686	Observational survey data	Perceived temperature deviation (IV) Belief in and concern for global warming (DV) Control variables: (1) actual temperature; (2) actual deviation; (3) gender; (4) education; (5) age; (6) income; (7) political affiliation; (8) environmental attitude; and (9) subjective knowledge of the phenomenon	Present temperature anomalies were associated with an overestimation of the frequency of similar past events, which was related to an increased belief in and concern for global warming.

Appendix B: for Chapter 4

Appendix B1: Description of each sport included in the interview study.

Sport	Brief description
Netball	A team sport played between two teams of seven players. It is similar to basketball although the rules, equipment and team numbers are different. There is no dribbling; no running with the ball; 7 players; ball passed within 3 seconds; ball & basket slightly smaller; no backboard; players designated to certain areas. It is played indoors and outdoors.
Racewalking	A long-distance discipline within the sport of athletics. It is different from running in that one foot must appear to be always in contact with the ground. Typically held on either roads or running tracks. Standard senior championships distances on the road are 20km and 50km.
Cricket	A team sport played between two teams of eleven players each. It is a bat-and-ball game played on a roughly oval grass field. Professional cricket is usually played outdoors.
Baseball	A bat-and-ball sport played between two teams of nine players each, taking turns batting and fielding. The game is played on an outdoor diamond-shaped playing field.
Field Hockey	A team sport structured in standard hockey format, in which each team plays with ten outfield players and a goalkeeper. Teams must drive a round hockey ball by hitting it with a hockey stick towards the rival team's shooting circle and then into the goal. Matches are played on grass, watered turf, artificial turf, synthetic field, or indoor boarded surface.
Golf	A club-and-ball sport in which players use various clubs to hit balls into a series of holes on a course in as few strokes as possible. It is a game played on a large outdoor course, usually with 18 holes.
Rowing	Sometimes called crew in the United States, is a sport of racing boats using oars. Rowing is divided into two disciplines: sculling and sweep rowing. In sculling, each rower holds two oars—one in each hand, while in sweep rowing each rower holds one oar with both hands. There are several boat classes in which athletes may compete, ranging from single sculls, occupied by one person, to shells with eight rowers and a coxswain, called eights. There are a wide variety of course types and formats of racing, but most elite and championship level racing is conducted on calm outdoor water courses 2km long.
Rugby Sevens	An outdoor team sport in which teams are made up of seven players playing seven-minute halves, instead of the usual 15 players playing 40-minute halves. The game is popular at all levels, with amateur and club tournaments generally held in the summer months.
Canoe Slalom	Competitive sport with the aim to navigate a decked canoe or kayak through a course of hanging downstream or upstream gates on river rapids in the fastest time possible. Competitions are usually held outdoors.

*It’s important to note that playing a sport indoors doesn’t necessarily equal protection from extreme heat.

Appendix B2: Additional participant characteristics

Participant pseudonym	Ethnicity	Political party most likely to support	Organisation governed by
Emma	White	Green	Netball Australia
Andrew	White	Left leaning	Athletics Canada / World Athletics
Jack	White	Green	England Cricket Club
Michael	White	Democrat	Major League Baseball
Jessica	White	Green	Great Britain Hockey
Oscar	White	Right leaning	Swedish Athletics / World Athletics
Megan	White	Liberal	Netball Australia
Matthew	White	Labour	European Gold Teaching Federation
Sarah	White	Labour	British Rowing
Hannah	Mixed	Democrat	USA Rugby
Luke	White	Labour / Green	Athletics Australia

Appendix B3: Full interview guide

Section 1: Knowledge and awareness	Could you tell me what heatwaves mean to you? What do you think causes a heatwave? How do they occur? Do you think heatwaves have become more common in your lifetime? Could you tell me about the impacts of heatwaves? Do you believe the impacts you have mentioned are being felt now? If yes, tell me more, why do you think that? If no, when do you think these impacts will start to be felt? Do you think the impacts will change in the future? If so, how and why?
Section 2: Attitudes and risk perceptions	What is your opinion of heatwaves? Could you tell me about the risks from heat? How well informed do you feel about heatwave risk? If heatwaves were to happen more often, how would that make you feel?
Section 3: Personal experience and behavioural response	Think of a time when you experienced a heatwave whilst competing in a sport event, could you tell me about it? Tell me about how the heat affected you prior, during and after the event? Tell me about after the event, how did you recover? How did the heat affect the people around you?
Section 4: Effectiveness of heat preparation and policies	How do you/your coach/team prepare for an event in the heat? Regarding the experience mentioned above, what safety measures did you/your team put in place for coping with the heat? How effective do you think these measures were? Could you describe the safety measures/policies the event organisers put in place during the event? Were they effective? How did you learn about these measures? Could you describe the safety measures/policies the event organisers put in place during the event? Do you have any ideas for other measures/policies for protecting athletes/staff/spectators during a heatwave?
Section 5: Climate change activism	Have you used your platform to talk about climate change? If so, how and why? If not, could you tell me why? Are there any barriers preventing you from speaking about climate change to the sport community?

Appendix C: for Chapter 5

Appendix C1: Participant characteristics

Characteristic	Study sample (N = 713)
Gender	
Male	354 (49.6%)
Female	356 (49.9%)
Other	3 (0.4%)
Age	
18-24	67 (9.4%)
25-34	125 (17.5%)
35-44	133 (18.7%)
45-54	123 (17.3%)
55-64	154 (21.6%)
65+	110 (15.4%)
Missing	1 (0.1%)
Ethnicity	
White	622 (87.2%)
Black/Black British/Caribbean or African	24 (3.4%)
Asian or Asian British	55 (7.7%)
Mixed, Multiple ethnic groups	5 (0.7%)
Other	7 (1%)
Political party affiliation	
Labour	250 (35.1%)
Conservative	162 (22.7%)
Liberal Democrats	62 (8.7%)
Green	58 (8.1%)
Unsure/Floating voters	133 (18.7%)
Would not vote	48 (6.7%)
Education	

GCSE/O Level equivalent	114 (16%)
A-levels or equivalent	158 (22.2%)
Higher education or equivalent	395 (55.4%)
Apprenticeship	9 (1.3%)
Other qualifications	26 (3.6%)
No qualifications	11 (1.5%)
Income	
Up to £4999	30 (4.2%)
£5000 to £14999	64 (9%)
£15000 to £24999	146 (20.5%)
£25000 to £39999	215 (30.2%)
£40000 to £74999	194 (27.2%)
£75000 or more	63 (8.8%)
Missing	1 (0.1%)
Sport Fandom (higher average scores indicate higher levels of sport fandom)	
1-2	315 (44.2%)
2-4	128 (17.9%)
4-6	125 (17.5%)
6-8	145 (20.3%)
Numeracy (correct responses)	
0	43 (6%)
1	127 (17.8%)
2	220 (30.8%)
3	323 (45.3%)

Appendix C2: Message transcripts for the basic heatwave information and lay person narrative groups

Condition group	Message
Basic heatwave information	A heatwave is defined as an uninterrupted period of exceptionally high temperatures. There's a threshold temperature for it to be described as a heatwave, and it varies from the mid to high twenties depending on which UK county you are located in. The threshold has to be reached or exceeded for three days in a row for it to be called a heatwave - if it doesn't last three days, it's considered a hot spell. Heatwaves can be dangerous to human health by placing significant strain on the body. Negative health effects of exposure to heatwaves can include cramps, fainting, heat exhaustion, heatstroke, dehydration and ultimately death. Older people and those with pre-existing health conditions such as heart disease are particularly at risk. Children and those who are less mobile may also be more vulnerable. Heatwaves place significant strain on the health and social care system and cause chaos for our infrastructure and businesses through cuts to water supplies, damaged rail networks and depleted workforces. As a result of climate change, hotter-than-usual days and nights are becoming more common in the UK and heat waves are expected to become more frequent, more intense and longer in duration. Increases in heatwaves may lead to more heat-related illnesses and deaths, especially if people and communities do not take steps to adapt. Even small increases in extreme heat can result in increased deaths and illnesses.
Statistical information only	A heatwave is an extended period of hot weather relative to the expected conditions of the area at that time of year, which may be accompanied by high humidity. According to the Met Office, a UK heatwave is met when a location records a period of at least three consecutive days with daily maximum temperatures meeting or

	exceeding the heatwave temperature threshold. The threshold varies by UK county in the range of 25°C and 28°C. Heatwaves place a strain on the heart and lungs. For that reason, the majority of serious illness and deaths caused by heat are respiratory and cardiovascular. Older people (65 and over), those with pre-existing health conditions and young children are particularly at risk. For example, in 2020, the highest temperature recorded was 37.8°C. The total excess deaths in England from the heat was 2,556, accounting for the highest rate of mortality since the 2003 and 2006 heatwaves. According to official statistics, nearly 90% of excess deaths during the heatwave occurred in the elderly population. Climate change is projected to raise average temperatures in the UK by 5°C by 2070, making the kind of temperatures seen in the mid-August heatwave of 2020 the norm for summers of the future. For every 1°C above a daily average temperature in the summer months, the UK currently sees a 2% rise in the death rate. Consequently, heat-related deaths in the UK could triple by 2050, to reach as many as 7,000 per year.
Lay person narrative	My name is Sam and I am an office worker in the UK. To me, a heatwave describes a period where temperatures are well above average. I first experienced such conditions during the 2018 heatwave. I live in an apartment on the top floor, and everything was baking, including myself. Even sat still, I could feel myself sweating and getting more agitated. I could barely sleep. At work, there was no escape. My office is on the 16th floor and by midday, the sun was piercing through the glass windows like a greenhouse. The hot air felt so heavy, it made me feel lightheaded and dizzy.

	And then the worst happened. I got a call to say my grandma had been admitted to hospital after collapsing from heatstroke. I felt so sick with worry, I had to get home. On the train, we were crammed in like sardines. It was like travelling in a moving oven. Only 30 minutes in, the train stopped. We had lost power and we were held on the track for hours. As the carriage got hotter, passengers began fainting and being sick. People were screaming for help. It was the most distressing day of my life. Since that day, I have learned that climate change is expected to make heatwaves longer, more intense and more common in the UK. This is a huge concern for me. If places get hotter, I worry that me and my family may not feel safe during hot weather in the future.
Sport narrative	My name is Sam, and I am an elite marathon runner from the UK. To me, a heatwave describes a period where temperatures are well above average. I first experienced competing in such conditions during the Tokyo 2020 Olympics. The heat and humidity was even more intense than what I'd been practising in the heat chamber. It was brutal out there. During the race, I remember it getting much harder, much earlier than normal. And the times were a lot slower as well. I was feeling lethargic, dizzy and constantly dehydrated. I felt like I was running with weights in both legs because there was so much heat and humidity and stagnated air. Although I knew if I stopped moving the pain would worsen. I remember feeling more exhausted than I've ever been, both physically and mentally. I just felt so weak and had less strength and less energy. Around the halfway mark, I remember seeing fellow athletes collapsed on the kerbside. They were stretchered away from the race

	and received treatment from medical professionals. I too became victim to the heat and ended up pulling out shortly after because I had nothing left. I was done. Since that day, I have learned that climate change is expected to make heatwaves longer, more intense and more common in the UK. This is a huge concern for me. I want people to enjoy my sport in the future, but if places get hotter, it may limit who can participate and access outdoor sports.

Appendix C3: Survey items

Demographic characteristics

Item	*Measurement Scale*
Gender	**What gender do you identify as?** 0 = Male 1 = Female 2 = Prefer not to say
Age	**Please state your age in years.** 1 = 18-24 2 = 25-34 3 = 35-44 4 = 45-54 5 = 55-65 6 = 65+ 7 = Prefer not to say *Participants state age in years*
Education	**Which of the categories below best describes your level of education?** If you are actually at school or college, please mark the level you are certain to complete 1 = No Qualifications 2 = GCSE/O-Level grade or equivalent 3 = A-Levels or equivalent 4 = Higher education or equivalent 5 = Apprenticeship 6 = Other Qualifications 7 = Prefer not to say
Party affiliation	**Please indicate the political party you are most likely to support.** 1 = Labour 2 = Conservative 3 = Liberal Democrat 4 = Green 5 = Unsure/floating voter 6 = Would not vote 7 = Prefer not to say
Income	**Please indicate your annual household income.** Please take into consideration that I am referring to the income of household as a whole before taxes and deductions, but after benefits. 1 = up to £4999 2 = £5000 to £14999

	3 = £15000 to £24999 4 = £25000 to £39999 5 = £40000 to £74999 6 = £75000 or more 6 = Prefer not to say
Ethnicity	**Choose one option that best describes your ethnic group.** 1 = White 2 = Black, Black British, Caribbean, or African 3 = Asian or Asian British 4 = Mixed, Multiple ethnic groups 5 = Other ethnic group 6 = Prefer not to say

Sport fandom ($\alpha = 0.96$)
Taken from Wann (2002)
*Higher ratings for items, and the higher the overall total scores for the given items, indicates a higher level of sport fandom.

Item		***Measurement Scale***
1	I consider myself to be a sport fan.	1 = Strongly disagree, 8 = Strongly agree
2	My friends see me as a sport fan.	1 = Strongly disagree, 8 = Strongly agree
3	I believe that following sport is the most enjoyable form of entertainment.	1 = Strongly disagree, 8 = Strongly agree
4	My life would be less enjoyable if I were not able to follow sport.	1 = Strongly disagree, 8 = Strongly agree
5	Being a sport fan is very important to me.	1 = Strongly disagree, 8 = Strongly agree

Risk perception ($\alpha = 0.96$)
P = Personal, S = Societal
Taken from Van der Linden (2015)

Item		***Measurement Scale***
1	How concerned, if at all, are you with climate change? (P)	1 = Not concerned at all, 7 = Very concerned
2	In your judgment, how likely are you, sometime during your life, to experience serious threats to your health or overall well-being, as a result of climate change? (P)	1 = Very unlikely, 7 = Very likely
3	In your judgment, how likely do you think it is that climate change will have very harmful, long-term impacts on our society? (S)	
4	How serious of a threat do you think that climate change is to the natural environment? (S)	1 = Not serious at all, 7 = Very serious
5	How serious would you rate current impacts of climate change around the world? (S)	
6	How serious of a threat do you believe that climate change is, to you personally? (P)	

7	How serious would you estimate the impacts of climate change for the United Kingdom? (S)	
8	How often do you worry about the potentially negative consequences of climate change? (P)	1 = Very rarely, 7 = Very frequently

Attitudes to hot weather

To what extent do you agree or disagree with the following?

Item		***Measurement scale***
1	I love hot weather	1 = Strongly agree; Agree; Neither agree nor disagree; Disagree; 5 = Strongly Disagree

Heatwave risk perception ($\alpha = 0.95$)
Taken from Howe et al (2019)

1. A heat wave is a period of unusually and uncomfortably hot weather. Thinking about your local area, how likely is it, if at all, that each of the following will be harmed by a heat wave in the next five years? If you're not sure, just give your best estimate.

Item		***Measurement scale***
1	Your health	1 = Definitely will not be harmed; About a 25% chance of harm; About a 50-50 chance of harm; About a 75% chance of harm; 5 = Definitely will be harmed
2	The health of others in your family	
3	The health of others in your community	

2. If a heat wave were to occur in your local area, how much, if at all, do you think it would harm the following?

Item		***Measurement scale***
1	Your health	1 = Would cause no harm at all; A little harm; Moderate harm; A great deal of harm; 5 = Would cause extreme harm
2	The health of others in your family	
3	The health of others in your community	

3. How worried, if at all, are you about the effects of heat waves on the following?

Item		***Measurement scale***
1	Your health	1 = Not worried at all; A little worried; Moderately worried; Very worried; 5 = Extremely worried
2	The health of others in your family	
3	The health of others in your community	

Discrete emotion

Using one or two words please state how you feel when you think about the issue of climate change?

Short form of the **Berlin Emotional Responses to Risk Scale**
Taken from Niszczota and Petrova (2021)

On a scale of 1 to 7 (where 1 = not at all, 7 = extremely), how do you feel when you think about the issue of climate change?

Item	***Measurement Scale***
Assured	1 = not at all, 7 = extremely
Hopeful	
Relieved	
Anxious	
Afraid	
Worried	

Appendix C4: Descriptive statistics of dependent variables for each condition

Message type	Variable	Pre-test mean (SD)	Post-test mean (SD)
Control	CCRP	4.77 (1.37)	4.76 (1.39)
	HWRP	2.08 (.74)	2.18 (.79)
	PA	2.21 (1.13)	2.27 (1.03)
	NA	3.94 (1.83)	3.83 (1.84)
Basic heatwave information	CCRP	4.86 (1.23)	4.93 (1.30)
	HWRP	2.10 (.72)	2.30 (.72)
	PA	2.15 (1.05)	2.22 (1.04)
	NA	4.09 (1.66)	4.07 (1.67)
Statistical information only	CCRP	4.68 (1.49)	4.89 (1.46)
	HWRP	2.02 (.69)	2.26 (.79)
	PA	2.04 (.87)	2.09 (.95)
	NA	3.95 (1.78)	3.90 (1.81)
Lay person narrative	CCRP	4.73 (1.31)	4.73 (1.37)
	HWRP	2.03 (.63)	2.32 (.75)
	PA	2.19 (.94)	2.07 (.92)
	NA	4.01 (1.66)	3.94 (1.65)
Sport narrative	CCRP	4.89 (1.40)	4.99 (1.37)
	HWRP	2.05 (.67)	2.39 (.79)
	PA	2.27 (1.06)	2.18 (1.11)
	NA	4.17 (1.83)	4.12 (1.76)

*CCRP climate change risk perception, HWRP heatwave risk perception, PA positive affect, NA negative affect