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Climate change-related heat stress and subjective well-being in Australia

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Abstract

There is mounting evidence that climate change impacts compromise peoples' well-being. Many regions of Australia have experienced record hot temperatures and more frequent and longer heat waves with substantial consequences for people, economies and ecosystems. Using data from an Australia-wide online survey with 1,101 respondents, we investigated the relationship between self-reported measures of heat stress and different dimensions of subjective well-being. After controlling for socio-economic factors known to affect well-being, we found that heat stress was linked to peoples' certainty about and planning for their future but not to their life satisfaction, happiness, social state, capabilities or their purpose in life. This result indicates that, while heat is not associated with present well-being, many people worry about the effect increasing heat will have on their future well-being. People who were uncertain about their future were also more likely than those who did not feel uncertain to think that heat compromised their productivity People who agreed that they were competent and capable in their activities rated their heat stress related productivity loss lower than those who disagreed. The findings are relevant for future studies using life satisfaction approaches to assess consequences of climate change impacts and to studies in 'happiness economics'. We recommend that future research on the impact of climate change on well-being goes beyond simply life satisfaction and happiness and tests multiple well-being dimensions.

Key words: Australia; climate change impacts; happiness; heat exposure; life satisfaction; positive psychology; uncertainty

1. Introduction

Recent studies estimated that there is a 95% chance global temperatures will rise more than 2^0C (Raftery et al., 2017) and a 93% chance that global warming will exceed 4^0C by 2100 (under a business-as-usual scenario in terms of greenhouse gas emissions; Brown and Caldeira, 2017). It is also expected that by 2100 half to two thirds of the world's population will live in areas that exceed a temperature tolerable to human beings for many days per year (Mora et al., 2017). Exposure to extreme heat compromises people's health (Kovats and Hajat, 2008) and cognitive abilities (Gaoua et al., 2011) and the health burden from heat is predicted to increase as a consequence of climate change (McMichael and Dear, 2010). Infants and elderly people (Bambrick et al., 2011) as well as those with pre-existing illnesses (Zhang et al., 2013; Hatvani-Kovacs et al., 2016) are among the most vulnerable to the health effects of heat. However, heat also reduces opportunities for recreation and affects productivity of healthy people in the society and workforce (Xiang et al., 2014; Zander et al., 2015; Hatvani-Kovacs et al. 2016; Kjellstrom et al., 2016) as there are clear and absolute limits to the amount of heat exposure an individual can tolerate (Kovats and Hajat, 2008; Sherwood and Huber, 2010).

The last few years (2013 to 2016) in Australia have all been record hot years (NASA, 2017) and only one of the warmest ten years occurred before 2005, while nine of the last ten years have been warmer than average (BoM, 2019). Average temperatures and the frequency and length of heat waves are predicted to increase further (Cowan et al., 2014). Hotter weather is the most readily apparent impact of climate change and, since 1900, exposure to extreme heat has killed more people in Australia than all other natural hazards combined (Coates et al., 2014) and has caused substantial economic losses because people feel less able to work at full capacity (Zander et al., 2015). The prominence of heat as an issue in Australia has engendered a substantial body of research on the impact of heat on human health. For example, during a particularly severe heat wave in 2009, ambulance call outs and direct heat-related hospital admissions in Adelaide were significantly higher than during previous heat waves (Nitschke et al., 2011). In Brisbane an extreme heat wave was also

63 associated with increased hospital admissions, particularly in areas of low-income households and
64 high population density (Hondula and Barnett, 2014). Mortality increased during almost all
65 heatwaves (1988 to 2009) in Brisbane, Melbourne and Sydney, particularly among women and the
66 elderly (Tong et al., 2014).

67 However, there is much less research on the effects of heat stress[1] more broadly on well-being
68 (subjective well-being SWB), of which physical health is one facet. Variations in well-being have
69 economic consequences (Piekałkiewicz, 2017) and hot weather reduces well-being even if the effects
70 are not physically manifest (Rehdanz an d Maddison, 2005; Connolly, 2013; Tsutsui, 2013).
71 However, the concept of well-being has many dimensions (Steptoe et al., 2015; Frey, 2018). The
72 most commonly used measure of well-being, usually evaluated from responses to a single question,
73 is life satisfaction, a person's evaluation of how they perceive her/his life has been so far (Frey et al.,
74 2010; García-Mainar et al., 2015). This measure of wellbeing is expected to increase in some cooler
75 parts of the world as mean temperatures rise but to decline in regions that are already hot (Maddison
76 and Rehdanz, 2011) and where climate change related extreme weather events, such as floods
77 (Luechinger and Raschky, 2009; Sekulova and van den Bergh, 2016; von Möllendorff and Hirschfeld,
78 2016), droughts (Carroll et al., 2009) and heat waves (Osberghaus and Kühling, 2016), become more
79 frequent or severe. Life satisfaction has also been used as a proxy for experienced utility in approaches
80 that monetarize the impacts of natural hazards (e.g., Luechinger and Raschky, 2009) with natural
81 disasters causing a welfare loss (called the life satisfaction approach; see Welsch, 2007).

[1] Heat stress is used to describe all health disorders related to exposure to extreme heat, including relatively mild effects such as physical and psychological heat exhaustion to more severe heat strokes (Parsons, 2003; Kovats and Hajat, 2008). Heat stress occurs when the body's temperature regulation fails and body temperature rises to critical levels, and is exacerbated by dehydration and high air humidity.

Impacts of climate change, including those caused by heat, on other dimensions of subjective well-being (SWB) are less well understood as is the extent to which SWB can mediate consequences of climate change impacts. Facets of SWB include positive emotions, engagement, satisfaction and meaning in life (OECD, 2013), all of which may be affected by heat with consequences for both the individual and the society. Disaggregating well-being into its various components allows both an appreciation of the complexity of responses to the impending higher temperatures and an understanding of where policy change can most effectively maintain well-being in the face of climate change. This paper therefore aims to 1) assess the impact of climate change-related self-reported heat stress on different dimensions of SWB of people living in Australia, and 2) understand the relationship between SWB and heat stress related productivity loss, a substantial economic consequence of heat stress for society as a whole (Zander et al., 2015). Our research contributes to the emerging but still scarce literature on socio-economic impacts of increasing heat (Kjellstrom et al., 2016; Reyer et al., 2017), which, to date, is largely localised (e.g. Williams et al., 2017) and limited to research on health impacts (mortality and morbidity) and vulnerability (e.g. Bi et al., 2011; Bambrick et al., 2011; Nitschke et al., 2011; Zhang et al., 2013; Hondula and Barnett, 2014; Tong et al., 2014; Hatvani-Kovacs et al., 2016).

2. Materials and methods

2.1. Framework and approach

Self-reported SWB has been found to be reliable and measurable (Di Tella et al., 2003; Frey and Stutzer, 2005). Three aspects of SWB can be distinguished: *evaluative* well-being (life satisfaction), *hedonic* well-being (feelings of happiness, sadness, anger, stress, and pain), and *eudemonic* well-being (sense of purpose and meaning in life) (Graham and Nikolova, 2015; Steptoe et al., 2015). In the field of environmental economics, evaluative well-being is usually measured in the form of life satisfaction (e.g. Maddison and Rehdanz, 2011; García-Mainar et al., 2015). Life satisfaction refers to a person's evaluation of how they perceive her/his life has been so far (Frey et al., 2010; García-

Mainar et al., 2015). Happiness refers to a person's current situation, capturing a momentary situation, effect, feeling or experience (Kahneman and Krueger, 2006), and, while a major goal of human beings, often defies formal definition because it is so contingent on individual context (Frey, 2018). Economists often use the two terms, 'happiness' and 'life satisfaction' interchangeably (e.g. Rehdanz and Maddison, 2005; Ferrer-i-Carbonell and Gowdy, 2007; Anand et al., 2011; García-Mainar et al., 2015; Sekulova and van den Bergh, 2016; Welsch and Biermann, 2016) and some (e.g. Frey, 2018) refer to happiness as the scientific term for SWB which can be measured through self-reported life satisfaction. In this study, however, we have purposely distinguished between happiness and life satisfaction and asked respondents to self-report on both in separate questions. We have also examined other elements of SWB, particularly its *eudemonic* dimensions, following OECD's guidelines on measuring SWB (OECD, 2013). In total, we measured six dimensions of SWB (Table 1).

[Table 1 here]

We hypothesise that heat stress levels are lower among people with higher levels of well-being, i.e. among those who are satisfied with their lives, are happy, have a sense of purpose or meaning in life, feel certain about their future and so are able to plan ahead, have supportive and rewarding social relationships, and who feel competent and capable in the activities that are important to them. We also hypothesise that those with higher SWB are less affected by heat stress in their daily activities, here measured as percentage productivity loss when heat stressed. Given the strength of evidence that happiness positively affects performance (e.g. Zelenski et al., 2008; Oswald et al., 2015; Bryson et al. 2017), we would expect a negative relationship between SWB and heat stress related productivity loss, although we acknowledge that there will be physiological thresholds beyond which the performance of even the happiest people is compromised.

2.2. Data collection and sampling

We undertook an online survey over a short period of time. This short time frame was important given our topic of perceived heat stress and encompassed a few days (between 9th and 15th of May

2017) at the time of the year when extremes of either heat or cold are highly unlikely so that thermal conditions on the day of the survey would have minimal influence.

The survey was piloted through in-person interviews with staff and students at Charles Darwin University (10) and also online (25). The online piloting was done through MicroWorkers, a platform where people can sign up to do jobs for payments. We screened for people living in Australia and offered AUD 1.50 to complete the survey. The questionnaire used for the piloting had an additional open-ended text box at the end where we specifically asked for feedback about the survey such as its clarity and time needed for completion. After the piloting, online and in-person, the wordings of some questions were slightly changed for the main survey, but the questions and the order were retained. We obtained ethics approval from the Charles Darwin University Human Research Ethics Committee. At the start of the online survey we sought informed consent of each participant.

For the final survey, we commissioned a research company (Survey Sampling International) to distribute the link to our online survey to members of their panel. The company's panel comprises about 300,000 people living in Australia. The panel is recruited through various online and offline sources (no self-recruitment) and is constantly updated. The research company randomly invited 5,000 people from their panel, thereby accounting for pre-defined distributions such as having an equal gender distribution, a distribution across Australia states and territories in proportion to their population size and had an age distribution (among people over 18) representing the national age distribution. No specific assumptions about work status and employment details were sought, since we wanted a good cross-section of the Australian population.

Panel members received an email with the invitation to participate and the link to our survey. No information was provided about the topic of the survey. In the invitation email panel members were only informed that it was a research survey, that it was likely to take about 15 minutes to complete and that they would receive between AUD 1 and AUD 2 upon completion (an amount set and paid by the research company).

We used an online survey because it is cost-efficient although we recognise that online surveys have limitations and potential biases. While data from online surveys do not differ significantly from those obtained using other survey modes (e.g. Nielsen, 2011; Windle and Rolfe, 2011), respondents to online surveys are often being better educated, younger and have higher incomes than those responding to other survey modes (e.g. Nielsen, 2011; Windle and Rolfe, 2011). Attitudinal characteristics may also differ between online and other modes (Nielsen, 2011; Windle and Rolfe, 2011).

The response rates of online surveys are also usually lower than in surveys of other modes (Shih and Fan 2009). The low response rates for online surveys might be because the benefits from the 'feeling of importance' when participating in a survey are lower in online surveys due to lack of personal contact with an interviewer or because the barrier not to participate is lower because personal contact is missing (Nielsen, 2011).

2.3. Questionnaire

We asked respondents to self-rate their level of heat stress in the last 12 months by asking "*Do you ever feel stressed by heat in what you are doing?*". Five categories were available of which respondents could choose one: "*Not at all*", "*Yes, but rarely*", "*Yes, sometimes*", "*Yes, often*" and "*Yes, very often*" (see questionnaire in Table S1 in Supplementary Materials). The heat stress question was not specifically targeted for activities at the workplace or at home, but included all activities and all times of the day (and night). Those respondents who chose any response but "*No, not at all*" were then asked if they felt they were less productive when feeling heat stressed. The question had five possible answers, which were the same categories as for the previous heat stress question. If respondents answered that they were, at least, rarely less productive, then their productivity loss was assessed through self-reported loss on a percentage scale from 1 to 100, with the corresponding question: "*On average, how much less productive -as a percentage- would you say you are on a scale from 1 (not much) to 100 (a lot) on a hot day?*" (see also Zander et al. (2015) for the same methodology to elicit heat stress and productivity loss).

To elicit life satisfaction, we asked "*All things considered, how satisfied are you with your life?*". The response was on a scale from 0 to 10, as used elsewhere (e.g. García-Mainar et al., 2015; von Möllendorff and Hirschfeld, 2016). This question on an 11-point-scale[2] is also used in European wide social surveys (EES[3]; see, e.g. Welsch and Biermann, 2014; and SILC[4], see, e.g. Welsch and Biermann, 2016) and in national surveys in Germany (German Socio Economic Panel; see, e.g., Osberghaus and Kühling, 2016) and Australia (HILDA; see, e.g. Ambrey and Fleming, 2014; Feddersen et al., 2016). Other elements of SWB were measured as agreement to a series of statements (see Table 1 and Figure 1) with responses on 4-point scales from 1 (strongly disagree) to 4 (strongly agree).

Physical and mental exertion of respondents' jobs were gauged on a scale from 1 to 10 with the associated question being: "*On a scale from 1 to 10, how physically (mentally) demanding is your job, with 1 not very demanding and 10 very demanding?*"

2.4. Data analyses

To explore the impacts of self-reported heat stress and various control variables on those SWB dimensions that were asked as "Agree-statements", we ran a series of logit models. The dependent variables were the answers to the SWB statement questions, grouped into 1 when respondents strongly agreed or agreed, and into 0 when they disagreed or strongly disagreed.

To explore the impacts of heat stress and control variables on life satisfaction we ran an ordered probit model with the dependent variable being life satisfaction, ranging from 0 to 10.

[2] Other common ranges of the scale to measure life satisfaction exist. Using a similar question on life satisfaction, a scale from 1 to 10 is often used (e.g. van Praag and Baarsma, 2005; Maddison and Rehdanz, 2011; Sekulova and van den Bergh, 2016). The Eurobaromter public opinion survey uses a qualitative rating scheme on a four-point scale, and data from it are the subject of many studies (e.g. Di Tella et al., 2003; Luechinger and Raschky, 2009). A similar qualitative approach with a 7-point scale is also common (e.g. Dear et al., 2002; Ferrer-i-Carbonell and Gowdy, 2007).

[3] http://www.europeansocialsurvey.org/

[4] https://www.bfs.admin.ch/bfs/en/home/statistics/economic-social-situation-population/surveys/silc.html

Otherwise we treated used all five categories for the variable “heat stress” (ranging from 0 (not at all heat stressed) to 4 (very often heat stressed)) as we did for the seven categories of income (see Table 2) and the five categories for education and for health status.

Bivariate analyses were applied to explain heat stress and percentage reduction in productivity from heat stress. Chi-square, ANOVA and Kruskal-Wallis (KW) tests were used to compare respondents’ reported heat stress categories for different socio-economic and demographic variables. If necessary, post hoc multiple comparison tests were conducted (Tukey's test after ANOVA and Dunn's test after KW). The KW test with post hoc comparison was also used to compare differences in the percentage productivity losses among respondents with different levels of SWB.

3. Results

3.1. Sample characteristics

3.1.1. Response rate

Of the 5,000 invited panellists and potential respondents, 1,175 started the survey (23.5%). Seventy-four people (6.3%) dropped out, leaving 1,101 complete responses, equivalent to a response rate of 22% which is in line with common response rates from online surveys (Shih and Fan 2009). Such a response rate was expected and is about average for response rates from online surveys (e.g. Shih and Fan, 2009). However, this response rate cannot be compared to response rates from mail or personal surveys. It is not clear how many of the 5,000 invited people actually saw the invitation and we do not know reasons for why they have not started the survey.

The distribution of responses across the states and territories reflects well the national distribution, as was expected given the instructions for survey distribution. Nearly 78% of the responses came from the three highest populated states (New South wales, Victoria and Queensland), which is the same as the actual distribution of the population (ABS, 2018; Table 2).

3.1.2. Personal characteristics

The mean age was 44.2 (SD: 14.6) with a median of 44 (Table 2). This is higher than the national median of 38 (ABS, 2016a), as expected because we only targeted adults whereas the national statistics include children. As requested of the survey company, the gender split was about 50/50. Sixty-two percent of respondents had an annual gross income of less than AUD 100,000 with 22% having incomes between AUD 100,000 and AUD 150,000. The median category was "AUD 61,000 to 80,000", which compares well with the median national gross income of about AUD 80,000 (AUD 1,616 weekly; ABS, 2017a). The national mean gross income is about AUD 110,000 (AUD 2,109 weekly; ABS, 2017a). However, in line with other studies (Nielsen, 2011; Windle and Rolfe, 2011), our sample was better educated than the average Australian - about 43% of respondents had a university degree (or were pursuing one), compared to 16% nationally (ABS, 2016a). About 63% of respondents had a partner, compared with 62% of adults over 18 nationally being married or in a de-facto relationship (ABS, 2016b).

More than half (55%) worked full-time, 28% part-time, 14% had casual jobs and less than 3% (31 people) were not in a paid position compared with national percentages of 57 (full-time), 20 (part-time) and 23 (casual) of those working (ABS, 2016c) and a national unemployment rate of 5.6% at the time of the survey (ABS, 2017b). About 78% of respondents had air-conditioning at home.

Most respondents (82%) believed humans are implicated in climate change, either as the main cause (43%) or equally with natural processes (39%), and about 5% (52) thought that climate change is a scam and not happening (Table 2). Most (78%) also thought that climate change threatens human health (24% strongly agreed and 54% agreed) and 72% said that they were worried about climate change for the next generation (22% strongly agreed and 50% agreed). Over half the respondents had personally witnessed climate change impacts (10% strongly agreed and 48% agreed).

[Table 2 here]

3.1.3. Subjective well-being

The answers to the statements measuring SWB are shown in Figure 1. There was no strong correlation between the measures (with $r > 0.7$; Table S2 in Supplementary Materials). The correlation (Spearman's rank) between happiness and life satisfaction was 0.57. The mean life satisfaction score was 6.6 (SD: 2.0). Responses to the variable '*My future is too uncertain for me to plan very far ahead*' showed the highest variation with 54% of respondents agreeing ('strongly agree' plus 'agree') and 46% disagreeing ('strongly disagree' plus 'disagree'). There were no responses to level 10 on the life satisfaction scale (see Figure S1 in Supplementary Materials for detailed responses to the 0 to 10 life satisfaction scale).

[Figure 1 here]

3.1.4. Heat stress related productivity loss

Ninety-nine percent of respondents who were heat stressed (and 88% of the total sample) reported productivity loss from heat stress with 35% in the categories "rarely" and "sometimes" and 53% in the categories "often" and "very often". On average, respondents were 43.2% less productive when heat stressed (SD: 27.9) with a median of 42%. The percentage productivity loss was highly dependent on the severity of heat stress ($F(4,1096) = 216.7$, $p < 0.01$). The mean productivity loss for people who were very often heat stressed was about twice that of people who were rarely heat stressed (68% vs. 33%). The mean productivity loss of those who were often heat stressed was 57%, and of those sometimes heat stressed 47% (Figure S2 in Supplementary Materials).

3.2. Explaining heat stress

Almost 90% of respondents reported that they had been heat stressed in the reference year 2016 with 58% of respondents in the categories "rarely" and "sometimes" and 31% in the categories "often" and "very often" (Table 2).

Bivariate analyses showed that the level of respondents' physical exertion (in their jobs and leisure time) was strongly positively associated with heat stress (KW = 44.54, df = 4, p-value <

0.0001) (Figure 2). The median level of physical exertion was highest for those very often heat stressed (6), often heat stressed (5) and sometimes heat stressed (5). There was also a positive, if weaker, association with the level of mental exertion (KW = 11.58, df = 4, p-value = 0.0207). The median level of mental exertion was 8 for those very often heat stressed, and 7 for those in all other heat stress categories. The level of self-reported heat stress did not differ with peoples' workloads (χ^2 = 7.35, df = 12, p-value = 0.8333).

Age was a weak predictor, at a 10% significant level (F = 2.93, df = 4, p-value = 0.0201) and without a clear direction. The Tukey test showed that those rarely heat stressed were significantly older than those often stressed (46.2 years versus 41.9). Average age did not significantly differ across the other heat stress categories (never: 44.5; sometimes: 44.4; very often: 42.7).

Women reported slightly higher heat stress levels than men (χ^2 = 17.84, df = 4, p-value = 0.0013) (Table 3) and health was negatively associated with heat stress (χ^2 = 64.95, df = 16, p-value < 0.0001) (Figure S3 in Supplementary Materials).

The state or territory in which respondents resided had no significant impact on heat stress (χ^2 = 26.32, df = 28, p-value = 0.5553), nor had the employment sector (χ^2 = 15.47, df = 16, p-value = 0. 4903) or having air-conditioning installed at home (χ^2 = 5.03, df = 4, p-value = 0.2843).

The attitudinal variables had highly significant impacts on self-reported heat stress (Table 3). Those who strongly agreed and agreed that climate change threatens human health reported more often that they were heat stressed often and very often (χ^2 = 68.50, df = 12, p-value < 0.0001). Most of those who thought climate change a scam were either never or rarely heat stressed. Climate change deniers had the highest share among those never heat stressed (χ^2 = 56.72, df = 12, p-value < 0.0001). However, those thinking that climate change is mostly caused by natural processes, i.e. those who think that the climate is changing but not due to human influence, had the highest share in the category "very often heat stressed". Those who were not worried for the next generation (strongly disagreed and disagreed that they were worried) were more likely to be never and less

likely to be often and very often heat stressed (χ^2 = 65.18, df = 12, p-value < 0.0001). Respondents who strongly agreed and agreed to have personally witnessed climate change impacts were more likely to be often and very often heat stressed and less likely to be never heat stressed (χ^2 = 83.50, df = 12, p-value < 0.0001).

[Table 3 here]

[Figure 2 here]

3.3. Heat stress and subjective well-being

Self-reported heat stress only significantly affected one SWB dimension, namely "*Uncertainty about the future*" (Table 4). Those who reported a higher level of perceived heat stress were more likely to have strongly agreed or agreed with the statement "*My future is too uncertain for me to plan very far ahead*" (see Figure 1 for the summary statistics of the SWB parameters). In other words, there was a negative relationship between reported heat stress levels and feeling certain about the future.

[Table 4 here]

The control variable "health status" was the strongest determinant of SBW and had a positive and highly significant effect on five of the dimensions (life satisfaction, happiness, social state, purpose in life and capabilities), and a negative effect on uncertainty about the future. Gender had a significant impact (p-value < 0.05) on only the social state with women more likely than men to agree or strongly agree that their social relationships are supportive and rewarding. Respondents with children were more satisfied with their lives (p-value < 0.05), more likely to experience a clear purpose in life (p-value < 0.01) and more likely to feel competent and capable (p-value < 0.1).

Age had a highly significant U-shaped effect on life satisfaction, happiness, purpose in life and social state, meaning that these dimensions of SWB declined with age down to a minimum (about 47) above which they increased. There was no age-effect on capabilities and certainty about the future.

Respondents in a partnership were more satisfied with their lives than those without (p-value < 0.01) and full-time employment was positively associated with life satisfaction and happiness (p-value < 0.05). People with lower income were less certain about their future. Education had no significant impact on any of the SWB dimensions.

3.4. Heat stress related productivity loss and subjective well-being

Productivity loss from heat stress was significantly higher for respondents who were uncertain about their future (KW = 46.92, df = 3, p-value < 0.0001) and lower for those who thought they were competent and capable in their activities that were important to them (KW = 14.46, df = 3, p-value = 0.0023) (Figure 3). Life satisfaction was not associated with the percentage productivity loss whereas happiness was (KW = 11.54, df = 3, p-value = 0.0091) with happier people having lower reductions in productivity when heat stressed. The result of the Dunn's post hoc test showed that the difference was only significant across the two categories "agree" and "disagree". There were no significant relationships between productivity loss and respondents' social status and their purpose in life.

[Figure 3 here]

4. Discussion and implications

4.1. Heat stress and subjective well-being

We did not find any associations between heat stress and five of the six SWB dimensions tested (life satisfaction, happiness, social status, purpose of life, capabilities). This was surprising and in contrast to the many economic studies showing a negative effect of natural hazards and climate change on life satisfaction and happiness (e.g., Carroll et al., 2009; Luechinger and Raschky, 2009; Maddison and Rehdanz, 2011; Sekulova and van den Bergh, 2016). Most of these studies investigated sudden onset hazards such as floods. The only study of which we are aware that investigated the effect of heat waves on life satisfaction did find a negative association (Osberghaus and Kühling, 2016). Our result also contradicts research in the field of positive psychology that

maintains there is an inverse relationship between general stress and happiness (e.g. Schiffrin and Nelson, 2010). One reason for the insignificant relationship between most SWB dimensions and climate change related heat stress could be that happiness and life satisfaction might increase the extent to which individuals are attuned to heat stress. Therefore, happiness and life satisfaction could have two conflicting consequences — an increase in the capacity of individuals to withstand heat stress but a greater sensitivity to or awareness of that stress. These consequences might cancel each other out and explain the finding that neither happiness nor life satisfaction was significantly related to perceived heat stress.

We did, however, find a positive association between heat stress and being too uncertain about the future to plan very far ahead. Our results might imply that peoples' greatest concerns about heat are not for their immediate SWB but the effect heat will have on them in the future. This would be in line with the high share of respondents (72%) who said that they were worried for the next generation given climate change. They might also be concerned, for instance, that heat will start to affect their health as they get older, if it does not already, or that they may need to move in the future if temperatures keep rising, making it difficult for them to plan ahead. While Feddersen et al. (2016), in a household panel study from Australia, found no relationship between life satisfaction and longer-term changes in climate this may have been because of differences in questionnaire design which did not assess other facets of well-being.

It could be that high levels of heat stress make people aware of future consequences of increasing heat and therefore uncertain about their future and not able to plan far ahead, or that people are generally uncertain about their futures, for other reasons, and that this makes them more susceptible to heat stress. This result underscores a risk of heat stress that appears to have been overlooked. Specifically, as noted by Joshi and Fast (2013), when individuals experience strong physical urges, such as the urge to consume food or shun the heat, they experience a sense of dissociation from the future.

Policies could be implemented that increase people's positive thinking about their future. On the workplace level these could be better job security and mentoring, making employees more certain about their future, and also training them on how to cope better with increasing heat, which is unavoidable in Australia, without compromising well-being (see Zander et al., 2017). On a national level, heat stress needs to be mitigated which implies tackling climate change in the first place. Given Australia is already facing ever-increasing record hot years (BoM, 2019), policies are needed that help people to cope with heat at home and at work and to become prepared to live in a hotter climate. Examples evolve around public infrastructure improvements aiming to increase evapotranspiration in the urban environment, such as green (e.g. parks) and blue (e.g. lakes) spaces or water-permeable pavements or aiming to increase solar reflectance through the use of cool materials in building facades, roofs, and pavements (Akbari and Kolokotsa, 2016). At home, policies helping people to retrofit their homes can help alleviate heat impacts (Rossi et al., 2015). At the same time increasing public awareness of how to behave in periods of extreme heat (e.g. appropriate clothing, drinking, resting, cooling, shading) can also help to reduce the health effects of heat (Kovats and Hajat, 2008). Heat wave action plans and guidelines already exist for some Australian cities (e.g. Adelaide, Darwin, Melbourne).

Heat stress itself was associated with well-known factors, such as physical exertion and health. Respondents in labour intense jobs perceived themselves, as expected, more stressed by heat (e.g. Kjellstrom and Crow 2013; Zander et al., 2015), as did those in poor health (e.g. Bi et al., 2013; Zhang et al., 2013). The finding that women felt more heat stressed was also expected: women have a different endocrinal physiology than men and lower heat tolerance levels (e.g. Havenith 2005; Witterseh et al. 2008). Connolly (2013) found that women are much more responsive than men to weather and that large deviations in rainfall and temperature from the usual weather (on the day of the survey) reduce women's' life satisfaction, but not men's. The state or territory where people lived had no significant impact on perceived heat stress levels. Given that we asked for perceived heat stress, this is not surprising People have different levels of tolerance and

406 acclimatisation and feel heat stressed at different temperatures. Another study from Australia on
407 perceived heat stress, using a different data set, also confirmed that the actual average temperatures
408 in the regions where people lived were not as important as the perceived temperatures (Zander et
409 al., 2017).

410 We found that the appreciation that climate change harms human health, concern for future
411 generations and the general belief that climate change is real and human-made was positively
412 associated with heat stress. This can be important in understanding who will take heat relief
413 measures on hot days, since beliefs are the best predictors of intentions to act (Azen and Budescu,
414 2003). Those who think that climate change is a scam might either really not feel stressed by heat,
415 they do not recognise their heat stress, or they do but deny it. Previous research found that climate
416 change scepticism is a barrier to behaviour which addresses climate change (Lorenzoni et al., 2007)
417 and those might be the group most vulnerable to heat stress, since they might not take precautionary
418 measures. Perceiving and having experience of climate change impacts is also important for
419 adaptation (Howe and Leiserowitz, 2013). Respondents who had personally witnessed the effects of
420 climate change also reported higher heat stress levels, as expected given that having experienced the
421 impacts of climate change fosters the belief that changes are happening (Akerlof et al., 2013; Howe
422 and Leiserowitz, 2013) and therefore makes people more attuned to potential impacts, such as heat
423 stress.

424 ### *4.2. Control variables explaining subjective well-being*

425 Some of the control variables had the expected signs in explaining the six dimensions of SWB, such
426 as the very strong impact of health (Clark et al., 2008). We found a U-shaped relationship between
427 age and life satisfaction, happiness, social state and purpose in life, as often found in health and
428 economic research on SWB (e.g. Dear et al., 2002; Blanchflower and Oswald, 2008; Steptoe et al.,
429 2015), but rather disputed in the field of psychology (Frijters and Beatton, 2012). We found only a
430 marginal gender-effect, related to respondents' social state. This is in contrast to two studies from
431 Australia, one of which found that women were more satisfied with their lives than men (Dear et al.,

2002), the other that men were more satisfied than women (Ambrey and Fleming, 2014), and other studies that found gender effects, but with mixed results (e.g. Chui and Wong, 2016). Having children had a strong significant positive effect on purpose in life and a weaker positive effect on capabilities but no effect on happiness and life satisfaction. This was not unsurprising given the mixed results of previous studies, ranging from positive (e.g. Angeles, 2014) to negative effects (e.g. Di Tella et al., 2003).

Education had no effect on any of the tested SBW dimensions, which was surprising since people with higher levels of education have more opportunities in life and are assumed to be happier (Frey, 2008). So was the relatively small effect of income, which we would have expected to have a stronger positive impact on SWB (Clark et al., 2008). Income was only positively associated with life satisfaction, in line with other studies that have found that people with higher incomes are better able to fulfil their material aspirations and also enjoy higher social status, which also increases life satisfaction (Frey, 2008). That income was negatively associated with being uncertain about the future was also unsurprising since people with low incomes are more likely to feel that they cannot adapt adequately to future situations, including increasing temperatures. One example relevant for coping with heat is the increasing use of air-conditioning needed to relieve heat stress at home and rising electricity costs.

4.3. Heat stress and productivity

Two aspects of peoples' SWB can counteract heat stress related productivity loss: their capabilities and the ability to plan ahead because they feel certain about their future. Those who felt certain, had a 10% lower loss in productivity than those uncertain and those feeling capable in the activities that are important to them considered that their productivity loss was 9% lower than those not feeling capable. This is in line with previous findings (Zelenski et al., 2008; Oswald et al., 2015), although we would have expected the same relationship between heat stress related productivity loss and life satisfaction. We asked specifically about productivity loss because of heat, and a positive valuation of the life situation might not help when the body cannot cope with the heat. Causality in

458 performance-happiness research is debatable, although recent research showed that happiness is an
459 input (e.g. Oswald et al., 2015), we could not test this in our research because of the survey design.
460 Almost all of our respondents who reported heat stress also reported productivity loss (99%),
461 confirming that these two factors are interrelated. Combating heat stress and related reductions in
462 performance, whether at work or in leisure time, is important for the society and economies of hot
463 countries. Without appropriate adaptations in workplaces, in the public and at home, costs will
464 increase as average temperatures become higher and heat waves more frequent and longer lasting
465 (Cowan et al., 2014). Heat relief might make people feel better now (less heat stressed) and also
466 more certain about their future so that they are more resilient as temperatures increase further.

467 ### *4.4. Life satisfaction and happiness*

468 Our paper contributes to the growing body of literature on happiness economics and impacts of
469 climate change on life satisfaction. With these comes the debate about definitions and dimensions
470 of SWB. In economics, including environmental economics, in many studies the term life
471 satisfaction is used synonymously with happiness (e.g. Rehdanz and Maddison, 2005; Anand et al.,
472 2011; García-Mainar et al., 2015; Sekulova and van den Bergh, 2016) and both for general well-
473 being. Here we considered separate measures for happiness, life satisfaction and other four
474 dimensions of SWB. Life satisfaction reflects on a person's life as a whole, whereas happiness is a
475 momentary state of the mind (Frey et al., 2010), in psychology called "positive affect" (Frey, 2008).
476 We found that self-reported levels of heat stress do not have a significant impact on either life
477 satisfaction or happiness (see Table 4).

478 Our result raises the question whether the variable "life satisfaction" should be used for
479 evaluating impacts of climate change and related extreme weather events, rather than other SWB
480 dimensions that assess people's well-being over a shorter time horizon and in the future. Most
481 people are unlikely to have been affected by climate change until fairly recent increases in the
482 frequency of hazards and their effects. They may also be aware that worse impacts of climate
483 change are predicted. Extreme events such as floods, heat waves and cyclones that occur

infrequently and over a short time frame are unlikely to change how people reflect on how their lives as a whole have been so far. We therefore suggest that multiple well-being dimensions need testing in any similar research, not only life satisfaction and happiness as these may not be affected by momentary effects of climate change, as shown here for heat stress.

In theory the different SWB dimensions measure different feelings. In fact, all the SWB dimensions we used are likely to intersect, which might be why we obtained similar results (e.g. positive impact of health on each dimension) and no significant impact of heat stress on neither of the SWB dimensions that expressed a positive feeling. For instance, people who reported higher life satisfaction are probably also happier, and both dimensions are positively correlated with capabilities and having a socially rewarding life (Frey, 2008). The question about uncertainty stood out, since it is not necessary that peoples' evaluation of their past and present well-being is correlated with their future certainty and prospects. For many, increasing heat from climate change seems to be one of the future uncertainties about which they are particularly concerned.

4.5. Limitations and research needs

A potential limitation of this study was that the data were obtained from self-reported measures so the results should be used with some caution in the interpretation. On the other hand, SWB measures have been used extensively in environmental and health economics and the derived data have been found valid for formal analyses (Di Tella et al., 2003; Frey and Stutzer, 2005). Moreover, Zander et al. (2015), to some extent, verified the use of self-reported heat stress and productivity measures, as they have been used in assessing the economic burden of chronical diseases. Their study used a different data set from Australia, where an online survey was repeated with two different sets of respondents but no differences in self-rated heat stress levels or productivity loss could be detected between the two surveys.

Sample bias could have arisen from the fact that respondents were relatively well educated, as often found with online surveys (see section 2.2). However, education had no significant impact

on heat stress, nor significantly moderated the observed pattern of results. Therefore, any bias that might have arisen in relation to the online sample would not have affected our results.

Future research could extend and refine this study. As already mentioned, future research on the impact of climate change on well-being has to go beyond life satisfaction and happiness, and multiple well-being dimensions need testing, particularly purpose in life and peoples' future prospects and certainties. Secondly, the facets of SWB could be manipulated experimentally, and hence the direction of causality established definitively, for both the causality between heat stress and SWB and heat stress related productivity loss and SWB.

5. Conclusions

Heat stress, which is likely to be experienced more frequently as climate change progresses, impedes human performance and labour productivity. This study found that 90% of respondents to an Australian-wide online survey conducted in May 2017 reported they had been stressed by heat in the previous 12 months. We found no negative impact of their heat stress on life satisfaction (evaluation of life as a whole) or on happiness (a momentary emotional state). Those with higher levels of reported heat stress, however, were less likely to be certain about their future or to feel able to plan ahead. This study also tested the premise that SWB could diminish the extent to which heat stress coincides with productivity loss. We found that the negative association between heat stress and productivity might be lower for people feeling strongly that they have purpose and meaning in life than those lacking purpose. Consequently, policies, practices, and procedures that enable individuals to feel more certain about their future, shape their life and pursue meaningful aspirations might be especially important as climate changes. Without these provisions, heat stress tends to orient the attention of individuals towards their more immediate concerns, potentially curbing their feelings about meaning in life, and thus amplifying the adverse effect of heat on productivity.

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Tables

Table 1: Dimensions of subjective well-being (SWB) and measures used in the study

Category of SWB	Measurement	Proxy used in study	Associate question and scale of self-reports
Evaluative	Life evaluation	Life satisfaction	"All things considered, how satisfied are you with your life?" Scale: 0 to 10
	Reflective evaluation of a person's social inclusions and networks	Social state	Agreement with statement "My social relationships are supportive and rewarding"
Hedonic	Assessment of emotional state / experience in life / "positive affect"	Happiness	Agreement with statement "I am happy."
Eudemonic	Assessment of a person's sense of meaning and purpose in life	Purpose in life	Agreement with statement "I experience a clear sense of purpose in life"
	A reflection of a person's certainty about their future	Uncertainty	Agreement with statement "My future is too uncertain for me to plan very far ahead"
	Assessment of a person's ability to cope with changing conditions	Capabilities	Agreement with statement "I am competent and capable in the activities that are important to me"

Social state, Happiness, Purpose in life, Uncertainty and Capability were all measured on a four-point scale: Strongly agree (4), Agree (3), Disagree (2), Strongly disagree (1)

742 **Table 2: Sample characteristics (N = 1,101)**

Personal and work-related characteristic	
Mean **age** (SD)	44.2 (14.6)
Female	50.3%
Health status (scale from 1: very poor to 5: very good) (SD)	3.8 (0.8)
Very poor (1)	0.6%
Poor (2)	2.5%
Fair (3)	26.4%
Good (4)	52.7%
Very good (5)	17.7%
Gross **income** in AUD (scale from 1: very low to 7: very high) (SD)	4.4 (1.8)
less than 20,000 (1)	4.2%
21,000 - 40,000 (2)	13.8%
41,000 - 60,000 (3)	18.3%
61,000 - 80,000 (4)	13.9%
81,000 - 100,000 (5)	15.7%
101,000 - 150,000 (6)	21.9%
151,000 - 300,000 (7)	12.2%
Education (scale from 1: very low to 5: very high) (SD)	3.3 (1.0)
Preparatory / elementary school (1)	2.6%
Secondary school (2)	22.8%
Intermediate Diploma / Certificate (3)	31.9%
Undergraduate degree (4)	27.6%
Postgraduate degree (5)	15.1%
Having **children**	30.5%
Having a **partner**	73.6%
Level of **physical exertion** of daily activities (scale from 1 to 10) (SD)	4.8 (2.6)
Level of **mental exertion** of daily activities (scale from 1 to 10) (SD)	6.8 (2.2)
Workload	
Full-time	55.4%
Part-time	27.5%
Casual	11.3%
Not in paid employment	5.8%
Sector of employment	
White collar (public administration, finance, insurance, education, research, real estate)	31.2%
Grey collar (wholesale and retail, transport, communication, policy, security)	24.1%
Blue collar (agriculture, cleaning, construction, electricity, fishery, forestry, manufacturing, mining, water and waste)	23.0%
Gold collar (medical, law)	13.1%
Pink collar (hospitality, tourism, entertainment and sport)	8.6%

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State or territory of residence[a)]	
New South Wales (NSW)	33.6%
Victoria (VIC)	24.9%
Queensland (QLD)	19.2%
Western Australia (WA)	9.6%
South Australia (SA)	7.7%
Australian Capital Territory (ACT)	1.9%
Tasmania (TAS)	1.9%
Northern Territory (NT)	1.2%
Climate change threatens human health	
Strongly agree	24.0%
Agree	54.2%
Disagree	17.9%
Strongly disagree	3.9%
Belief in climate change and its **cause**	
Climate change is mainly caused by human activity	42.7%
Climate change is partly caused by natural processes and partly by human activity	12.9%
Climate change is mainly caused by natural processes	39.7%
Climate change is a scam and I don't believe it is happening	4.7%
Worry for the next generation because of climate change	
Strongly agree	21.6%
Agree	50.2%
Disagree	22.0%
Strongly disagree	6.2%
Personally **witnessed** the impacts of climate change	
Strongly agree	10.1%
Agree	47.8%
Disagree	34.2%
Strongly disagree	7.9%
Do you ever feel **stressed by heat** in what you are doing?	
No, never	10.6%
Yes, rarely	24.4%
Yes, sometimes	33.7%
Yes, often	18.9%
Yes, very often	12.4%

744 [a)] National population distribution across states and territories:

745 NSW: 32.0%; VIC: 25.9%; QLD: 20.0%; WA: 10.4%; SA: 7.0%; ACT: 1.7%; TAS: 2.1%, NT: 1.0% (ABS, 2018)

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748 **Table 3: results of bivariate analyses of factors affecting heat stress (N = 1,101)**

	Heat stress category				
	Never (10.6%)	Rarely (24.4%)	Sometimes (33.7%)	Often (18.9%)	Very often (12.4%)
Workload					
Full-time	32 (11.6%)	69 (24.9%)	112 (31.6%)	49 (20.2%)	41 (11.6%)
…Part-time	12 (10.6%)	39 (22.8%)	56 (37.0%)	30 (16.2%)	20 (13.5%)
Casual	71 (7.6%)	152 (24.8%)	193 (35.7%)	123 (19.1%)	71 (12.7%)
Not in paid job	2 (6.5%)	9 (29.0%)	10 (32.3%)	6 (19.4%)	4 (12.9%)
Occupation					
White collar	28 (8.1%)	92 (26.7%)	120 (34.9%)	65 (18.9%)	39 (11.3%)
Grey collar	35 (13.2%)	64 (24.2%)	92 (34.7%)	39 (14.7%)	35 (13.2%)
Blue collar	29 (11.5%)	59 (23.3%)	84 (33.2%)	49(19.4%)	32 (12.6%)
Gold collar	13 (9.0%)	28 (19.4%)	50 (34.7%)	32 (22.2%)	21 (14.6%)
Pink collar	12 (12.6%)	26 (27.4%)	25 (26.3%)	23 (24.2%)	9 (9.5%)
State or territory					
New South Wales (NSW)	39 (10.5%)	76 (20.5%)	122 (33.0%)	78 (21.1%)	55 (14.9%)
Victoria (VIC)	31 (11.3%)	76 (27.7%)	97 (35.4%)	47 (17.2%)	23 (8.4%)
Queensland (QLD)	23 (10.9%)	49 (23.2%)	69 (32.7%)	37 (17.5%)	33 (15.6%)
Western Australia (WA)	15 (14.2%)	25 (23.6%)	37 (34.9%)	16 (15.1%)	13 (12.3%)
South Australia (SA)	5 (5.9%)	22 (25.9%)	30 (35.3%)	21 (24.7%)	7 (8.2%)
Australian Capital Territory (ACT)	1 (4.8%)	9 (42.9 %)	6 (28.6%)	3 (14.3%)	2 (9.5%)
Tasmania (TAS)	2 (9.5%)	7 (33.3%)	6 (28.6%)	4 (19.0%)	2 (9.5%)
Northern Territory (NT)	1 (7.7%)	5 (38.5%)	4 (30.8%)	2 (15.4%)	1 (7.7%)
Gender					
Female	39 (7.0%)	136 (24.5%)	188 (33.9%)	112 (20.2%)	79 (14.3%)
Male	78 (14.3%)	133 (24.3%)	183 (33.5%)	96 (17.6%)	57 (10.4%)
Health					
Very bad	0 (0.0%)	0 (0.0%)	3 (42.9%)	0 (0.0%)	4 (57.1%)
Bad	3 (10.7%)	1 (3.6%)	6 (21.4%)	10 (35.7%)	8 (28.6%)
Fair	25 (8.6%)	63 (21.6%)	95 (32.6%)	60 (20.6%)	48 (16.5%)
Good	55 (9.5%)	151 (26.0)	214 (36.9%)	112 (19.3%)	48 (8.3%)
Very good	34 (17.4%)	54 (27.7%)	53 (27.2%)	26 (13.3%)	28 (14.4%)
Air-conditioning at home					
Yes	90 (10.4%)	210 (24.3%)	295 (34.2%)	170 (19.7%)	98 (11.4%)
No	27 (11.3%)	59 (24.8%)	76 (31.9%)	38 (16.0%)	38 (16.0%)

Climate change threatens health	19 (7.2%)	53 (20.1%)	76 (28.8%)	57 (21.6%)	59 (22.3%)
Strongly agree	54 (9.0%)	154 (25.8%)	216 (36.2%)	117 (19.6%)	56 (9.4%)
Agree	32 (16.2%)	49 (24.9%)	74 (37.6%)	26 (13.2%)	16 (8.1%)
Disagree	12 (27.9%)	13 (30.2%)	5 (11.6%)	8 (18.6%)	5 (11.6%)
Strongly disagree					
Cause of climate change					
Mainly human	44 (9.4%)	100 (21.3%)	163 (34.7%)	108 (23.0%)	55 (11.7%)
Human and nature	35 (8.0%)	131 (30.0%)	160 (36.6%)	64 (14.6%)	47 (10.8%)
Mainly nature	24 (16.9%)	24 (16.9%)	36 (25.4%)	29 (20.4%)	29 (20.4%)
Scam	14 (26.9%)	14 (26.9%)	12 (23.1%)	7 (13.5%)	5 (9.6%)
Worry for next generation					
Strongly agree	20 (8.4%)	54 (22.7%)	62 (26.1%)	55 (23.1%)	47 (19.7%)
Agree	42 (7.6%)	133 (24.1)	205 (37.1%)	110 (13.2%)	63 (7.4%)
Disagree	36 (14.9%)	64 (26.4%)	92 (38.0%)	32 (13.2%)	18 (7.4%)
Strongly disagree	19 (27.9%)	18 (26.5%)	12 (17.6%)	11 (16.2%)	8 (11.8%)
Witnessed climate change impacts					
Strongly agree	10 (9.0%)	24 (21.6%)	21 (18.9%)	30 (27.0%)	26 (23.4%)
Agree	33 (6.3%)	118 (22.4%)	193 (36.7%)	117 (22.2%)	65 (12.4%)
Disagree	49 (13.0%)	103 (27.3%)	138 (36.6%)	51 (13.5%)	36 (9.5%)
Strongly disagree	25 (28.7%)	24 (27.6%)	19 (21.8%)	10 (11.5%)	9 (10.3%)

749 White collar: public administration, finance, insurance, education, research, real estate

750 Grey collar: wholesale and retail, transport, communication, policy, security

751 Blue collar: agriculture, cleaning, construction, electricity, fishery, forestry, manufacturing, mining, water and waste

752 Gold collar: medical, law

753 Pink collar: hospitality, tourism, entertainment and sport

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Table 4: Impact of heat stress and control variables on different dimensions of subjective well-being (N = 1,101)

	Life satisfaction		Happiness		Social state		Purpose in life		Uncertainty		Capabilities	
	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Constant	0.57	0.40	-1.32	1.05	-0.18	1.01	-0.63	0.91	4.95***	0.90	0.18	1.30
Heat stress	0.01	0.03	-0.11	0.07	-0.03	0.07	-0.01	0.06	0.22***	0.06	-0.10	0.09
Age	-0.07***	0.02	-0.09**	0.04	-0.11***	0.04	-0.13***	0.04	-0.04	0.04	-0.07	0.06
Age squared	0.001***	<0.001	0.001**	0.001	0.001***	<0.001	0.002***	<0.001	<0.001	<0.001	0.001	<0.001
Health	0.58***	0.04	0.97***	0.12	0.71***	0.10	0.70***	0.10	-0.63***	0.09	0.65***	0.13
Income	0.03	0.02	0.07	0.05	0.07	0.05	0.06	0.05	-0.16***	0.04	0.004	0.07
Female	0.08	0.07	-0.03	0.17	0.36**	0.16	0.09	0.15	-0.22	0.14	0.12	0.21
With children	0.18**	0.08	0.11	0.20	0.21	0.19	0.59***	0.17	-0.04	0.16	0.42*	0.25
With partner	0.33***	0.08	0.14	0.20	0.22	0.18	-0.02	0.17	-0.27	0.16	0.13	0.25
Education	-0.01	0.03	-0.02	0.08	0.06	0.08	0.07	0.07	0.04	0.06	0.01	0.10
Full-time	0.17*	0.09	0.48**	0.24	-0.12	0.23	0.32	0.21	-0.23	0.20	-0.08	0.32
Part-time	-0.01	0.10	0.26	0.25	0.04	0.24	0.30	0.22	-0.13	0.21	-0.20	0.34
Nagelkerke R^2	0.20		0.17		0.12		0.13		0.19		0.10	

***, **, * = significance at 1%, 5%, 10% level

Life satisfaction: measured on a scale from 0 to 10, 0 = very dissatisfied, analysed using an ordered probit model.

All other dependent variables were coded 1/0 as per agreement to statements (see section 2.4) and analysed using binary logit models

Heat stress: measured on a scale from 1 to 4, 1= rarely

Health: measured on a scale from 1 to 4, 1= very bad

Income: measured on a scale from 1 to 7, 1 = very low

Education: measured on a scale from 1 to 5, 1 = low level

Figures

Figure 1: Responses to a series of statements on subjective well-being (N = 1,101)

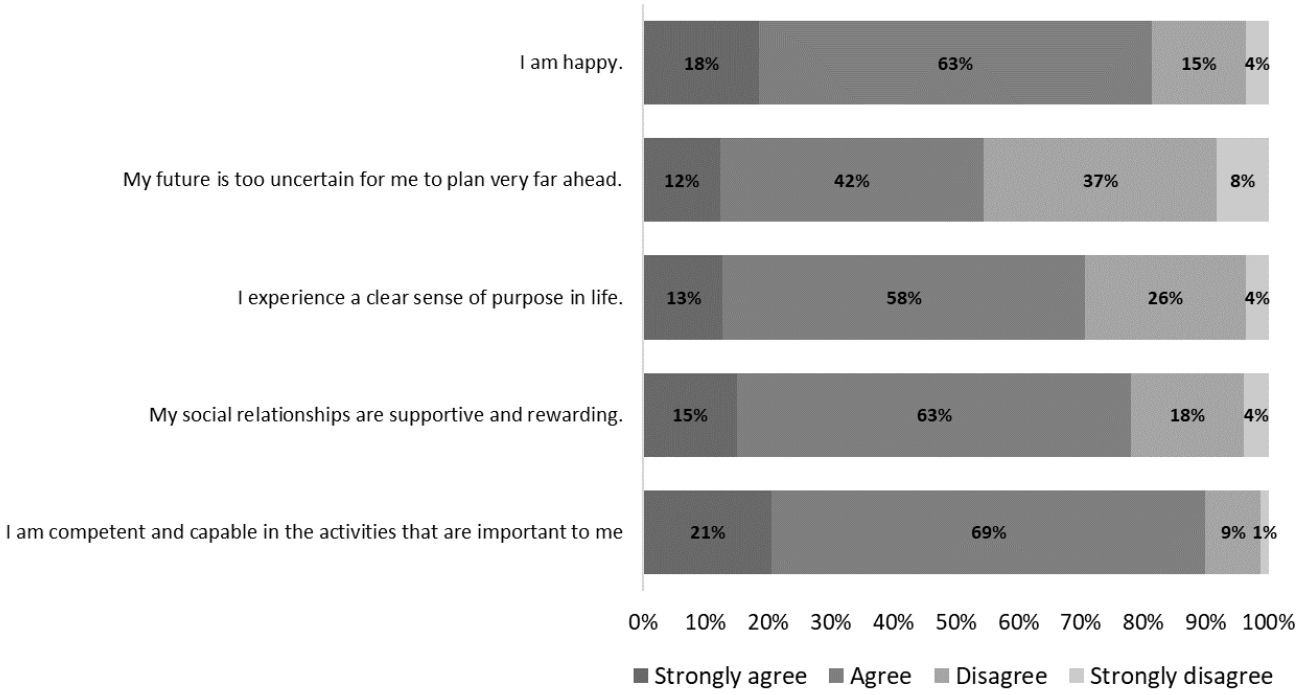


Figure 2: Boxplots showing the relationships between heat stress and physical (left) and mental (right) exertion, both measured on a scale from 1 (very low) to 10 (very high) (N = 1,101)

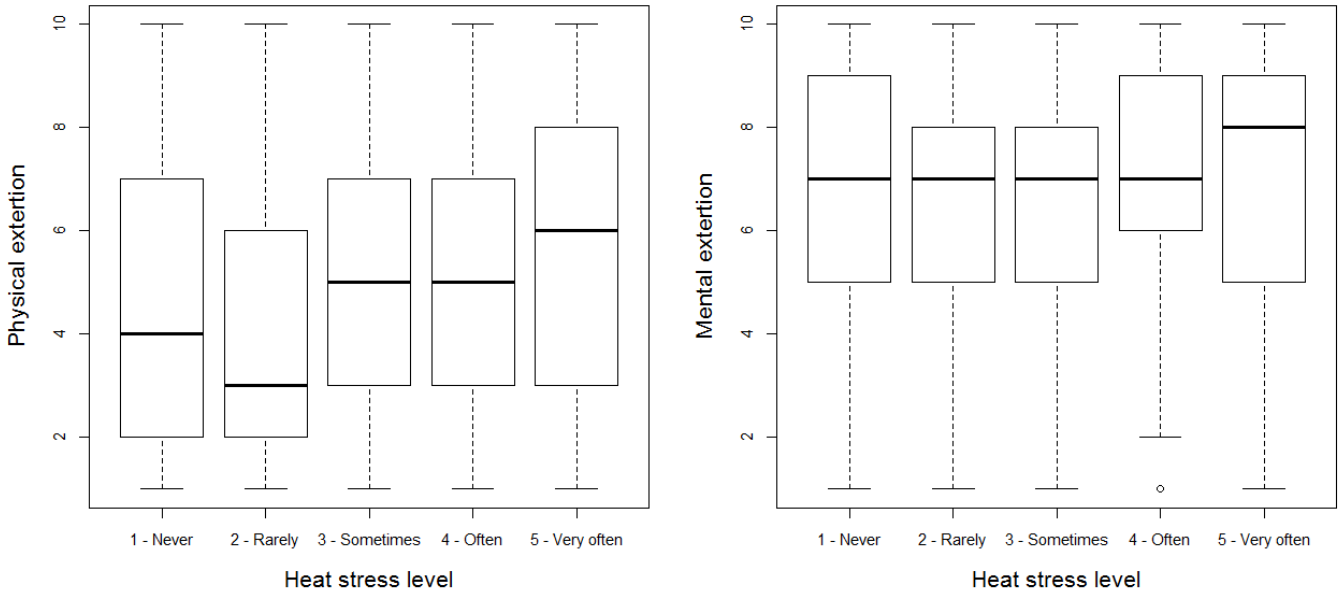
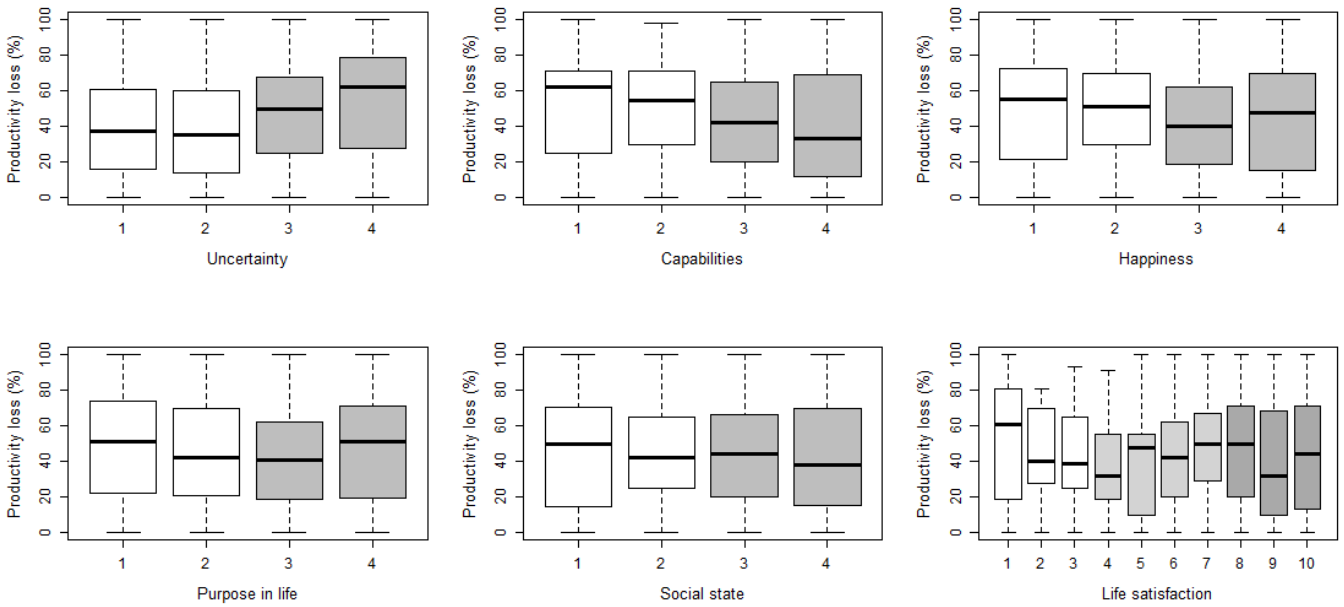


Figure 3: Impact of different dimensions of subjective well-being on heat stress related subjective productivity loss



x-axes: 1 = strongly disagree; 2 = disagree; 3 = agree; 4 = strongly agree for statements capturing respondents' subjective well-being dimensions (see Table 1):

'Uncertainty = My future is too uncertain for me to plan very far ahead

'Capabilities' = I am competent and capable in the activities that are important to me

'Happiness' = I am happy

'Purpose in life' = I experience a clear sense of purpose in life

'Social state' = My social relationships are supportive and rewarding

x-axis for 'Life satisfaction': ordinal scale from 1 to 10 assessing statement 'All things considered, how satisfied are you with your life?'