Who Is Feeling the Heat?

Vulnerabilities and Exposures to Heat Stress—Individual, Social, and Housing Explanations

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Abstract

Ongoing climate change has led to an increase in extreme temperatures, which influence both the environment and human beings. However, not everyone is affected by heat stress to the same degree. This article analyzes who is affected by subjective heat stress. Individual and social indicators of vulnerability and exposure—mediated by conditions of housing and living environments—are considered simultaneously, from the sociological perspective of social inequality influences. Using local data from an empirical survey in Nuremberg, Germany, the article shows that age, individual health, and social contexts all explain variations in how people experience heat stress. It is further hypothesized and confirmed that heat exposure due to disadvantaged housing conditions or distance from green space increases the levels of subjective heat stress. When looking at differences in levels of subjective heat stress, the consideration of heat exposure due to social vulnerability and socioeconomic reasons offers some explanations.

Keywords

exposure, heat stress, housing, living environment, vulnerability

Climate change is taking place, with multiple effects on both nature and human beings. This means that increases in overall temperature, in the number and duration of hot periods, and in extreme weather events—such as sudden heavy rains—are all very likely (IPCC 2013). Climate change influences determinants for health such as mortality, water supply, and air quality (Krämer et al. 2013). The effects of extreme heat waves on mortality occur particularly in large cities and urban areas (e.g., Bittner 2014; D'Ippoliti et al. 2010; Robine et al. 2008). One example of such an extreme event is the heat wave during the summer of 2003: approximately seventy thousand more deaths than usual were reported throughout Europe during August 2003 as a consequence of the heat (Patz et al. 2005; Robine et al. 2008). Extreme heat events entail certain costs for a country; they have an effect on the work performance and productivity of individuals, resulting in a reduction

Nature and Culture Volume 12, Issue 2, Summer 2017: 137–161 © Berghahn Books
doi:10.3167/nc.2017.120203 ISSN 1558-6073 (Print) · ISSN 1558-5468 (Online)

of gross domestic product (GDP; Hübler et al. 2008). Therefore, it is important to look more closely at the effects of heat on the individual and how this leads to individual strains.

Since the middle of the 1980s there has been ongoing discussion on whether the impacts of environmental hazards are equally or unequally distributed among the population. Ulrich Beck argued that "poverty is hierarchic, [but] smog is democratic" (1992: 36) and that ecological perils in the water or the air are hazards for everyone, regardless of social class or social position (1992, 2007). Members of the environmental justice movement disagree with Beck's position and argue that adverse environmental effects are unequally distributed (e.g., Brulle and Pellow 2006; Cutter 1995; Mielck and Bolte 2004; Mohai and Bryant 1992). Many studies have linked (social) vulnerability, that is, the ability of an individual to be resistant and resilient to climate hazards, to climate change and environmental hazards (see, e.g., Cutter et al. 2003; Cutter et al. 2008; Harlan et al. 2013; Holand et al. 2011; Tapsell et al. 2010). There are indications that heat events seem to have a greater impact on some social groups, such as those with low economic status or certain (ethnic) minority groups (Harlan et al. 2006; Klinenberg 2002), than others. In 2009 Jobst Conrad claimed that the social sciences should also contribute sociological explanations on climate research and climate change. Prior to the middle of 2000s, most climate research had been conducted in the natural sciences, mainly by climatologists. Since then a growing number of studies have focused on the social aspects of heat and its impacts (e.g., Großmann et al. 2012; Heudorf and Schade 2014; Uejio et al. 2011; Wanka et al. 2014; Wolf et al. 2010). However, there is still a need for further research.

This article will combine findings on vulnerability with those on exposure to heat, and will focus on the impact of periods of heat, how individuals are affected by heat, and the resulting (subjective) heat stress for those individuals. "Subjective heat stress" means here the individually perceived experience of heat, and can be very different between individuals.[1] Moreover, the article concentrates on the questions of how individual and social situations and living environments contribute to the explanation of individual subjective heat stress, and which determinants lead to an unequal distribution of heat stress. It is assumed that individuals experience subjective heat stress before physical heat-related problems actually occur, which ultimately lead in some cases to heat-related illness or even mortality. The following section presents the theoretical framework, explaining the relation between social inequality and the experience of heat stress through two central mechanisms: "exposure" and "vulnerability" to heat. Thereafter, the next section summarizes results from previous research and presents hypotheses on subjective heat stress. Empirically, this article makes use of a survey on climate change from Nuremberg, a major city in southern Germany. The data set and operationalization are presented in the following section. Then, a regression model is applied to estimate individual, social, and housing effects on heat stress. The article concludes with a discussion of results and some perspectives for future research.

A Theoretical Framework

In order to explain heat stress, the social inequality of environmental health impacts need to be discussed. The theoretical concept of environmental justice gives useful insights into the explanation of the unequal distribution of environmental burdens (Elvers 2011). Generally speaking, environmental injustice occurs when a "specific social group is disproportionately affected by environmental hazards" (Brulle and Pellow 2006: 104). The first discussions on unequal and unfair distribution of adverse environmental exposure took place during the late 1970s in the United States, and environmental justice then began as a civic movement when inhabitants of communities started to organize themselves to protest against environmental hazards in their neighborhoods. The starting point was an incident of industrial intoxication in a housing area through chemical disposals at Love Canal (Levine 1982). Research by Robert Bullard (1983) revealed that more than 80 percent of waste sites in the United States were located in poor, mainly African American neighborhoods.

Environmental justice expresses two interpretations of the resulting inequality: First, that these are mechanisms of discrimination or even racism (Bullard 1983; Elvers 2011), for example, when people of color and/or poor people who do not have the (political) power to offer resistance are subjected to environmental hazards. Second, that in areas with high ecological burdens, those with higher incomes move away, leaving the cheap and ecologically disadvantaged area to poorer people ("drift hypothesis"; Maschewsky 2000: 78). These mechanisms lead to unequal exposure and vulnerability to environmental hazards.

Based on the theory of environmental justice, Andreas Mielck and Gabriele Bolte (2004) hypothesize that socioeconomic status influences exposure to environmental risks and thus also to heat stress. *Exposure* here is the possibility of being at risk of suffering adverse impacts of heat, mainly caused by housing situation and living environment. Moreover, socioeconomic status also influences a person's vulnerability to environmental risks. *Vulnerability* is understood here as the "demographic and socioeconomic factors that increase or attenuate the impacts of hazard events on local populations . . . [or] who is at risk" (Cutter et al. 2009: 2–3) due to certain life circumstances. Vulnerability, exposure to environmental risks, and low socioeconomic status may all lead to an increase in environmental health problems, here understood as *heat stress* (see Figure 1).

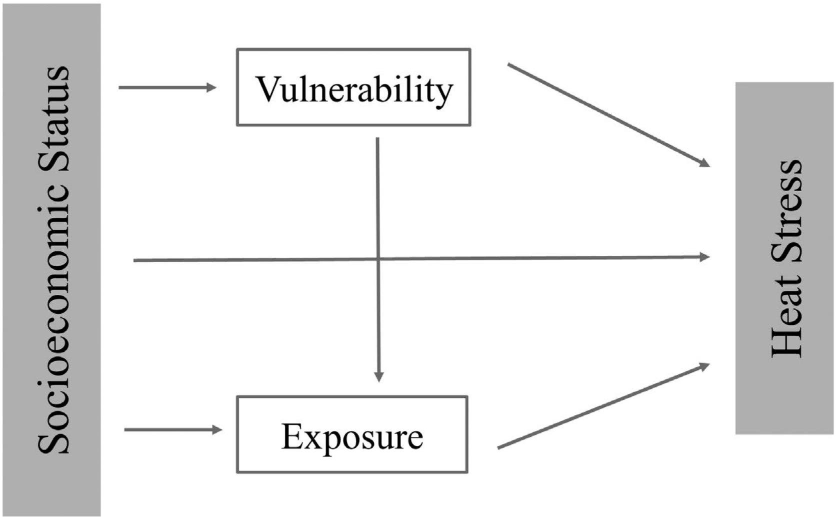

Figure 1 ▪ Mechanisms leading to heat stress.

Mechanisms of Vulnerability and Heat Stress

The main *personal factors* that determine heat vulnerability are related to age and individual health status; that is, older people suffer more from high temperatures than do younger people (Welzer and Kolland 2014). The ability to cope with heat also relates to a person's physical state; one biological experimental study showed that aged cells show less ability to cope (physiologically) with heat stress (Ando et al. 1997), illustrating that older adults have less personal resistance and fewer resources against heat. Their "thermoregulation" is not as vital as in the younger population (Wanka et al. 2014), and individual health status is crucial, as a weak immune system inhibits the individual's ability to defeat the heat. Healthy people cope better with extreme heat events than do those with an adverse health status; the chronically ill have less physical ability to defeat an overload of heat and are therefore at higher risk of mortality during hot periods (D'Ippoliti et al. 2010; Hertel et al. 2009; Klinenberg 2002). In addition to physical health reasons for experiencing a certain level of heat stress, there are social and behavioral factors at work, for example, the mental health status or the general stress level of an individual influencing the experience of subjective heat stress. The mental health status of older people is also influential in their experience of heat stress; for example, the elderly more often suffer from dementia, and this has an influence on their behavior. Due to physical or mental sickness it may be more difficult for them to leave the house, or they may even be completely bedridden. To protect oneself against the heat, appropriate health behavior (e.g., regular fluid intake) is essential, and due to age or mental problems such as dementia, it can be harder for older people to achieve this, therefore meaning they are at higher risk of suffering from subjective heat stress (Semenza et al. 1996; Wanka et al. 2014).

Thus, it is expected that *older people experience more subjective heat stress (H1)*. Moreover, *people with health impairments are expected to experience more subjective heat stress (H2), especially older people (H2a)*, compared to young and healthy people.

Another important factor is a person's socioeconomic status. Socioeconomic background is one of the most important indicators for social inequality. Social inequality in general can be categorized as either vertical or horizontal; vertical social inequality is measured by differences in education, occupation, and income, whereas horizontal inequality is measured by individual characteristics such as gender or ethnicity. Both dimensions of social inequality help to explain (environmental) health differences (Bolte and Kohlhuber 2009; Mielck and Heinrich 2002). It is assumed that socioeconomic status directly influences an individual's experience of heat stress, but also indirectly influences it through higher exposure, individual vulnerability, and adaptive capacities (Wilhelmi and Hayden 2010). All these processes lead to subjective heat stress. Socioeconomic status is a determining factor in the resources available to an individual to react to heat exposure. A *moderate* income allows someone to spend more on reacting to heat exposure than a *low* income, for example, by being able to afford extra sun protection features in the home such as air conditioning, which was found to be an important factor in the reduction of heat mortality (Semenza et al. 1996).

People with low incomes are forced to move into areas with low rents, as they cannot afford high housing expenses (Maschewsky 2000), but by their nature, areas with low rents usually have more environmental burdens and are less attractive (Bolte and Kohlhuber 2009; Uejio et al. 2011). Therefore, people living in poor areas experience a double burden of greater exposure to heat and, with fewer resources for managing it, greater vulnerability to the heat, thus experiencing more heat stress (Harlan et al. 2006; Smargiassi et al. 2009; Uejio et al. 2011).

An individual's educational background may also be influential. Education is known to influence individual health outcomes and also to determine health behavior (Cutler and Lleras-Muney 2006). Concerning this research, education is assumed to influence the experience of subjective heat stress through the knowledge of appropriate reactions during a heat wave (e.g., taking a break from hard work during hot periods) and generally through a healthier lifestyle, which itself is partly determined by a higher level of education (Schulz and Northridge 2004). Hence, it is expected that *people with high economic status and a higher degree of education experience less subjective heat stress (H3).*

Finally, social capital is considered as an aspect of vulnerability that might influence the experience of subjective heat stress. Social capital can play an important role in the process of adaption to climate change (Adger 2003). Social capital as such is understood as a resource that lies in a person's affiliation to a group and the potential knowledge that emotional or material support could be provided by other members of the group (Bourdieu 1983). The relationships between individuals can be differentiated by strong or weak ties (Granovetter 1973) that may offer different services. Strong ties, called "bonding social capital," may supply direct support in the form of emotional or financial support, while weak ties—also called "bridging social capital"—may offer flow of information and exchange of knowledge (Adger 2003; Granovetter 1973). Social capital can be important for coping with the impacts of extreme weather events or other environmental hazards. Bonding social capital may be useful especially for the vulnerable or socially excluded, while bridging social capital could play an important role in managing collective resources and collective action by spreading information or reacting to environmental risks (Adger 2003). Social support from family and other social contacts can reduce individual vulnerability and strengthen the ability to master periods of high temperatures (Wanka et al. 2014), while socially isolated people are more exposed to heat, as no one else is available to help or monitor the degree of exposure (Klinenberg 2002).

From these considerations it is presumed that individuals with more social capital are better prepared, in terms of resources and adaptive capacities (see also Wilhelmi and Hayden 2010), to react to environmental heat risks. Thus, it is hypothesized that *socially integrated individuals experience less subjective heat stress (H4).*

Mechanisms of Environmental Exposure and Heat Stress

Within a city, the occurrence of *urban heat islands*[2] is seen as the central climatic problem; they determine, among other factors, the level of exposure to heat. From a perspective of urban climatology, several factors mediate the development of urban heat islands; degree of cloud coverage, wind speed, the sky view factor, and the amount of green space and number of water features in an area all affect warming. An increase of heat in the urban climate is related in part to anthropogenic heat emission, which is caused among other things by high population, building, or traffic densities or by high levels of heat emission in general. It is also related to the degree of surface sealing, the usage of heat-absorbing materials, and smog radiation (Kuttler 2013).

Aspects of the living environment as well as living space ought also to be taken into account when considering environmental exposure (Mielck and Bolte 2004). On the level of neighborhood, deprivation in a neighborhood is related to higher environmental exposure, for example, through a higher exposure to traffic or industrial air pollution. With these features, as argued earlier, the development of high temperatures resulting in higher heat stress is more likely. Low socioeconomic status is also often related to poor housing conditions such as dangerous building materials and few recreational features (Bolte and Kohlhuber 2009; Mielck and Bolte 2004; Van Lenthe 2006). It is clear that housing conditions, as argued by climatology experts, determine the degree of heat absorbed into the dwelling, and therefore also that poor conditions increase exposure to heat. Thus, *a disadvantaged living situation may explain variations in subjective heat stress (H5).*

A green physical environment cools down the air and may reduce the heat level in an apartment or dwelling. Greenery also has a positive effect on psychological well-being (Maas et al. 2009). Moreover, greenery in the immediate surrounding provides opportunities for healthy behavior and serves as a meeting place to socialize with others, thus buffering stress in daily life (Maas et al. 2009; Van den Berg et al. 2010). It is expected, therefore, that *few (and/or no access to) green recreational facilities in the living environment increases subjective heat stress (H6)*.

State of Research

Since the occurrence of heat waves in recent decades, and following their impact on the population, many scholars have focused on the explanation for several heat-related health outcomes such as heat-induced illness and morbidity as well as heat mortality (Robine et al. 2008; Semenza et al. 1996; Smargiassi et al. 2009). Many studies on heat mortality confirm relations between age (Baccini et al. 2008; Bittner 2014; D'Ippoliti et al. 2010; Klinenberg 2002; Robine et al. 2008; Siuda et al. 2010), health and chronic illness (Hertel et al. 2009; Klinenberg 2002; Semenza et al. 1996), socioeconomic factors, and heat mortality (Harlan et al. 2013; Klinenberg 2002; Uejio et al. 2011). As the focus of this article is subjective heat stress, I will further discuss studies in more detail that address subjective heat stress.

Age and poor health status have both been found to be related to greater subjective heat stress (Pfaffenbach and Siuda 2012; Siuda et al. 2010). Also, having a low economic status, living in urban areas, and being socially isolated increases the risk of heat stress (e.g., O'Neill et al. 2009; Wanka et al. 2014). Isabell Maras and colleagues (2013) conclude that it is the accumulation of inequalities among vulnerable groups that impose the most heat stress.

Furthermore, housing conditions and social living situations, which are influenced by socioeconomic status, also have an effect on the perception of subjective heat stress. A research study from Leipzig showed that people living on their own—especially single mothers—and the unemployed suffer more from heat than do others (Kabisch and Großmann 2010). Among older people the perception of subjective heat stress varies. Another study showed that older people with little physical impairment and high flexibility in their daily routines experience little subjective heat stress compared to the older people with physical constraints (Großmann et al. 2012). Furthermore, the spatial structure of the city, as well as the living environment itself, had an effect. The amount of green space around the buildings decreases heat burdens and also affects the measured temperatures in the area.

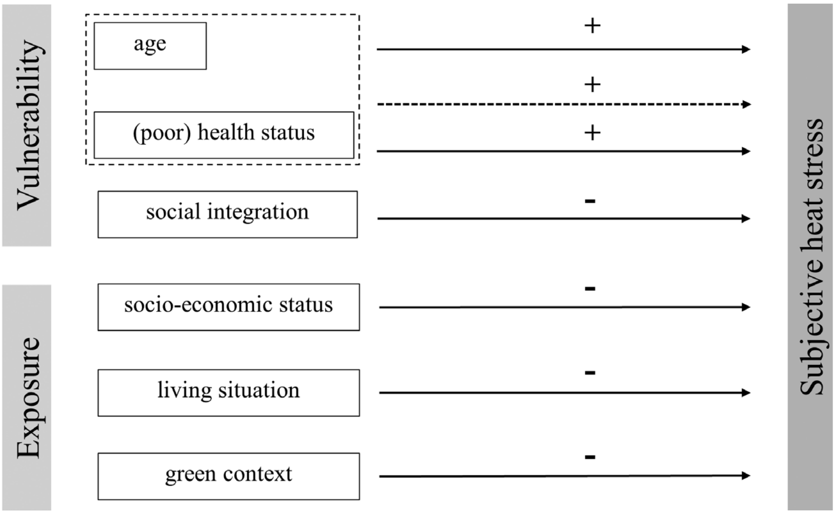

Figure 2 ■ Hypotheses on subjective heat stress.

Indoor evening temperatures in particular are related to the perception of heat stress, though this varies according to individual heat adaption behavior (Franck et al. 2013). People living higher up in a building and those living in older houses with no thermal insulation reported greater degrees of subjective heat stress (Franck et al. 2013; Großmann et al. 2012). Another study among older people in Vienna found that living areas that have a tendency to develop "heat islands" impose heat stress on individuals. According to this study, it is the *adaption strategy* of an older person to heat that lowers their experience of heat stress rather than heat itself (Wanka et al. 2014).

Results for the relation between the social context and heat stress differ. Many studies find a relation between social isolation and heat stress (Klinenberg 2002; O'Neill et al. 2009; Uejio et al. 2011; Wanka et al. 2014). A study on the adaptability of older people to heat suggests contradictory results, where strong bonding social capital could also contribute to heat vulnerability instead of reducing it (Wolf et al. 2010), which would oppose the argumentation of W. Neil Adger (2003).

The research results confirm the stated theoretical hypotheses regarding the impact of (social) vulnerability and heat exposure in the living context on subjective heat stress. Figure 2 summarizes the hypothesized determinants on subjective heat stress, which will be operationalized and tested in the following sections.

Data and Methods

The analyses are based on individual data from a representative survey ("Adaption to Climate Changes in Nuremberg 2011") collected during the summer of 2011 in Nuremberg. The sample contains people living in two city districts (historical city center and the west side), both of which are disadvantaged during summer in respect to temperature and vulnerability to climate change (Umweltamt 2012). The historical city center is the cultural and tourist center of the city; it is characterized by a high proportion of housing under protection because of historical interest, very dense housing, and a low degree of greenery. The west side is heterogeneous, including great industrial areas, historic apartment buildings, and a population of low socioeconomic status. It is also shaped by a high degree of concreting, low degree of greenery, and little access to existing green spaces.[3]

The data was collected via computer assisted telephone interviewing (CATI) and paper and pencil interviewing (PAPI). People who had a registered phone number in the official phone books were contacted via phone (35 percent); the other group (65 percent) received a paper questionnaire that was dropped in their mailbox.[4] Accounting for neutral dropouts (e.g., invalid number or address, respondent had moved away), a total response rate of 15.7 percent was achieved. For further information on the study, the design, and response rates, see Reinhard Wittenberg and colleagues (2012).

Dependent Variable

The dependent variable for the analyses was the *subjective heat stress* of respondents, which as measured on a 10-point Likert scale. Respondents were asked to estimate their individual overall experience of heat stress ("On average, how affected are you by heat?").[5] The scale ranged from 1 ("not affected at all by heat") to 10 ("very much affected by heat"). On average people reported medium heat stress (4.85 points; for more details, see Table 3 in the appendix); the variable is almost normally distributed, which allows us to apply multivariate linear regression models.[6]

Independent Variables

Indicators for individual *vulnerability* were measured by the age of the respondent and social context. *Age* was categorized into four groups:[7] respondents from 18 to 35 years, from 36 to 55 years, from 56 to 70 years, and 71 years and above. *Physical health status*[8] of a person was measured using a dummy for *problems climbing stairs* (with 44 percent of respondents having mild or severe problems when climbing stairs) and a dummy showing whether a person had any *physical health difficulties in the last four weeks (*47 percent of the respondents had a physical health problem on one or more day in the last four weeks).[9] *Social isolation* was measured by *family status*: comparing people who are single or divorced/widowed to those who are married or cohabiting. Additionally, people were asked to report their *number of personal contacts* and the *frequency of meeting* friends ("once a month or less," "a couple of times in the month or weekly," "a couple of times a week or daily").

The *socioeconomic status* was measured through *personal net income* per month. This question resulted in a rather high number of missing values on this variable ($n = 248$, or approximately 21 percent of respondents; see Table 3).[10] Additionally, *employment status* ("working full time" or "part-time" vs. "not employed or retired" and "other statuses") and the *degree of education* in three categories ("lower education," "middle education," and "higher level of educati*on*") were included in the analyses.[11]

Determinants for exposure to heat in the living environment were operationalized as follows. The living situation was measured using several features, such as the *floor level* of the apartment. This was used as a possible proxy for heat in the apartment, as higher levels usually have higher temperatures. People living on the ground floor or in the basement were compared to those living on the first, second, third, fourth, or higher levels.[12]

Another proxy for exposure to heat in an apartment and also for socioeconomic status is the size of the apartment an individual lives in. Respondents were asked to give information on the *square-meter size of their apartment/house*, assuming that people in larger apartments or houses can avoid heat by using a cooler room. A dummy was added when the house or apartment allowed the *opportunity to go outside* by means of a balcony, terrace, or a garden. The survey also comprised a subjective measure on *greenery in the living environment*. Respondents were asked to state how far away (walking in minutes) the next green

Table 1 ■ Distribution of the objective measures of the living context.

Street type	*Pedestrian area*	18.3%
	Small street	56.2%
	Bigger street with two or more lanes	25.5%
Amount of green in the surrounding	*Very little or no green*	63.9%
	A little to a lot of green	36.1%
Green yard or garden	*Yes*	60.8%
	No	39.2%
Traffic noise (during daytime)	*No traffic noise (< 45 dB)*	23.6%
	45 db and more noise	76.4%

space or park is, and also, if so, how often they use it ("seldom or never," "between once a month and once a week," or "a couple times a week to daily").

Additionally, several *objective measures of living context* were included for each respondent (see Table 1). The immediate living surroundings of each respondent was coded via Google Maps, considering the *street type*, the *amount of green* in the living surroundings directly in front of the house, and the existence of a *green yard or garden* at the house. The amount of *traffic noise* was coded from noise maps of the Environmental Office of Nuremberg. Noise was approximated into "no traffic noise" during daytime versus "45 db and more" traffic noise.[13]

The *geographical distance* to the next green space or park was included by the direct "as the crow flies" distance in meters coded for each address (with an average distance of 650 meters to the next green park; see Table 3).[14] This allowed an estimation of the cooling effects of green surroundings and also an actual measure of distance to the next park.[15] Unfortunately, no objective temperature measure for exposure could be included in the analyses, as the questionnaires distributed via PAPI could not refer to a certain date or day temperature.

In the analyses we *controlled* for the gender of a person (1 = male), household size (in four categories: "one," "two," or "three or more people"), presence of children (1 = yes vs. 0 = no), and *district*. As the west side is diverse qua average income and buildings, it was separated for the purpose of analyses into poorer and richer areas. The average income per district was put into three categories: "rich west side," "poor west side," and "historical city center."

Additionally, the mode of data collection was controlled for (CATI vs. PAPI). A complete overview of the descriptive values of the variables and the characteristics of participants in the sample is given in the Appendix. The analyses were carried out with Stata 13. The multivariate linear regression on heat stress was carried out in two steps, including interactions on health and age in a second model.

Results

The regression results show that factors of vulnerability and exposure can explain variation in heat stress (see Table 2). The final model explains 13 percent (adjusted R^2) of the variance on heat stress.

The analyses show effects of the age of a person on the subjective level of heat stress. People aged between thirty-six and fifty-five years old experience significantly more heat stress compared to younger people (i.e., those aged between eighteen and thirty-five years). Older people (i.e., those aged seventy and over) experience significantly more heat stress than people in the younger age groups. This older age group is already retired and could also be more affected by a poorer health status. The study does not reject the primary hypothesis (H1) at a significant level ($p < 0.1$). It is also supported that people with (physical) health impairments experience significantly more heat stress (H2). In order to test whether older people with health impairments experience higher levels of heat stress than older people in general, we estimated an additional model including an interaction on health status and age to test the different age groups when experiencing health problems.[16] People who have problems climbing stairs experience significantly more heat stress. Physical health problems are also highly significant. Those with any health restrictions experience more heat stress. This is especially true for people over seventy years old. So, as assumed, people with health problems have higher chances of experiencing a greater degree of heat stress (H2a). When controlling for health, an effect for people between thirty-six and fifty-five years still remains.

The results show further that the number of contacts a respondent has is indeed connected to subjective heat stress, and that the more social interactions a person has the lower their perception of heat stress is. The frequency of meetings with friends and other contacts also matters. When people report that they meet their friends weekly or even a couple of times per week, the perception of heat stress decreases. Being alone with no partner, divorced, or widowed has no effect on

Table 2 ■ Results of a multivariate linear regression on heat stress.

	Full Model			*Model with Interactions*		
	Coefficient	**P-value**	**Stand. error**	Coefficient	**P-value**	**Stand. error**
Gender (1 = male)	−0.061	0.712	0.166	−0.079	0.636	0.166
Age in categories: *18 to 35 years (ref.)*						
36 to 55 years	0.845 **	0.001	0.245	0.619 *	0.048	0.313
56 to 69 years	0.528 +	0.079	0.300	0.196	0.586	0.359
70 and older	0.794 *	0.019	0.338	0.420	0.290	0.397
Level of education: *lower (ref.)*						
middle	0.284	0.238	0.240	0.298	0.215	0.240
higher	0.213	0.367	0.236	0.217	0.359	0.236
Monthly net income	0.000	0.992	0.000	0.000	0.964	0.000
Employment status: *not employed (ref.)*						
full–time	−0.159	0.465	0.218	−0.158	0.471	0.218
part–time	0.010	0.974	0.300	0.009	0.977	0.301
Having children (1 = yes)	−0.269	0.204	0.211	−0.274	0.196	0.212
People living in the household: *one person (ref.)*						
two persons	0.174	0.453	0.231	0.181	0.435	0.232
three and more persons	0.460	0.136	0.308	0.477	0.125	0.311
Family status (1 = alone)	0.155	0.480	0.219	0.173	0.430	0.219
Health difficulties when climbing stairs (1 = yes)	0.521 **	0.005	0.184	0.494 **	0.007	0.184
Health difficulties in the last 4 weeks (1 = yes)	0.975 ***	0.000	0.166	0.482	0.113	0.304
Age * health: *18 to 35 years and health difficulties in the last 4 weeks (ref.)*						
36 to 55 years and health difficulties in the last 4 weeks				0.508	0.240	0.432
56 to 69 years and health difficulties in the last 4 weeks				0.778 +	0.080	0.444
70 and older and health difficulties in the last 4 weeks				0.826 *	0.071	0.457
Frequency of meeting: *once a month or less (ref.)*						
a couple of times per month	−0.458	0.143	0.313	−0.457	0.144	0.312
weekly	−0.555 +	0.059	0.294	−0.548	0.062	0.294
more than once a week	−0.658 *	0.019	0.281	−0.641 *	0.023	0.281
daily	−0.744 *	0.048	0.377	−0.751 *	0.046	0.376
Number of contacts	−0.025 **	0.008	0.009	−0.025 **	0.009	0.009
Square meters of housing	−0.005 +	0.073	0.003	−0.005 +	0.078	0.003

Table 2 ■ (continued)

	Full Model			*Model with Interactions*		
	Coefficient	**P-value**	**Stand. error**	Coefficient	**P-value**	**Stand. error**
Floor level: *basement or ground floor (ref.)*						
1st floor	0.462 +	0.072	0.257	0.474 +	0.065	0.257
2nd floor	0.982 ***	0.000	0.257	0.974 ***	0.000	0.257
3rd floor	0.491 +	0.067	0.267	0.492 +	0.067	0.268
4th floor or higher	0.770 **	0.005	0.275	0.753 **	0.007	0.276
"Outside option" at house (1 = yes)	−0.448 *	0.019	0.190	−0.451 *	0.018	0.190
Perceived distance to park area in minutes	0.025 +	0.084	0.015	0.025 +	0.086	0.015
No (use of) park areas	0.206	0.587	0.379	0.202	0.594	0.379
Use of green areas: *never or seldom (ref.)*						
monthly up to weekly	−0.051	0.808	0.211	−0.046	0.829	0.211
more than once a week to daily	0.037	0.860	0.211	0.020	0.925	0.211
Traffic noise—daytime (1 = more than 45 db)	0.277	0.165	0.200	0.278	0.164	0.199
Green at house (1 = little up to a lot of green)	−0.037	0.845	0.189	−0.044	0.814	0.189
Street type: *big street (ref.)*						
small street	0.017	0.933	0.202	−0.015	0.941	0.203
pedestrian area	0.378	0.136	0.253	0.341	0.179	0.254
Green backyard or garden (1 = yes)	0.088	0.623	0.178	0.055	0.757	0.179
Distance to park area in meters	−0.082	0.806	0.333	−0.082	0.805	0.333
Sampling region: *(rich) west side district (ref.)*						
(poor) west side district	0.203	0.397	0.239	0.210	0.380	0.239
historical city center	0.212	0.424	0.265	0.237	0.373	0.266
Constant	4.909 ***	0.000	0.616	4.147 ***	0.000	0.628
Number of observations	868			868		
Adjusted R^2	0.126			0.127		

Note: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, + $p < 0.1$
Controlled for: survey mode (CATI/PAPI)

subjective heat stress, nor has the number of household members. It seems that the social contacts a person reports and the frequency of interacting with these social contacts are the important factors for variation in subjective heat stress. As assumed, the fact that being socially integrated reduces levels of subjective heat stress (H3) can be (partially) confirmed.

The socioeconomic context (income situation and level of education) shows no effect in the analyses. Having higher levels of education compared to people with a low level of education as well as being in a full-time or part-time job compared to not being employed does not influence the perception of subjective heat stress (H4).[17] A small effect of socioeconomic situation can be seen in the effect of size of apartment. Being able to afford a larger-sized apartment is related to income. The results show that a larger living space reduces heat stress slightly, although this effect is very small and only significant on a 10 percent level (ten additional square meters reduce heat stress by 0.05 points on the heat stress scale).

The effect of exposure to heat because of an adverse housing situation leads to higher levels of heat stress. Living on higher floors leads to more heat stress. Age and floor level have the strongest effect on heat stress measured by the beta coefficients.[18] Referring to the hypotheses, the study does not reject the hypothesis (H5) on the influence of indicators for housing situation on heat stress.

Finally, a robust result is that the perceived proximity to a green area influences the perception of heat stress. People living closer to a green area and who estimate a short walking distance to the nearest park feel less strained by heat. However, there was no support for the assumption that it also matters how frequently this park area is used.

The objective measures of living context and district does not have an effect on individual subjective heat stress; the direct living context coded via Google Maps does not seem to matter. Traffic noise has no effect on subjective heat stress in the multivariate model. Other indicators such as the greenery around the house or the actual distance to the next park did not show any effect. The assumptions regarding the green context can only partly be confirmed in the analyses (H6).

Discussion

This article has shown that age and health status in particular are indicators for subjective heat stress. Similar to the results from the study in

Leipzig, this study confirms an effect of the living and housing contexts as important for the experience of subjective heat stress (see Großmann et al. 2012). These indicators are most likely to depend on socio-economic status. In this, the results discussed here support the arguments of environmental justice—that social inequality in the population results in unequal distribution of environmental hazards, in this case with regard to subjective heat stress. Social indicators of vulnerability and exposure could (partly) explain why variations in subjective heat stress are not equally distributed among the population. Future research could investigate more closely how the institutional context can reduce these differences and how the different theoretical mechanisms have an effect on specific life circumstances, as, for example, employed people have different structures to their day than families with children or old people.

The objective measures of living environment did not show any effect on heat stress. One explanation for this could be that while it does matter whether people have green areas available within a close distance, as green space cools down the temperatures (Franck et al. 2013), the subjective perception of distance to the nearest green space better reflects the real proximity to the area. The measurement of the distance to the nearest large park-like area is therefore less important, as the actual meters do not express personal walking pace.

Even though quite a number of determinants are included in the analyses, the explained variance remains rather low (13 percent). This might be due to missing hard measures of physical exposure to temperatures, as no real temperature measure (indoors or outdoors), due to the sampling, was included in the analyses. Furthermore, an overall measure for subjective heat stress was used instead of a precise measure for heat stress differing, for example, between the subjective heat stress at home, outside, or at certain times. A precise differentiation between certain contexts of everyday life and hours of the day would possibly explain more of the variance by housing conditions that other research has shown (see Franck et al. 2013). Unfortunately, we could not include a control on the actual temperature during the period of data collection, as the paper questionnaires were dropped in the mailbox and sent back by mail. During the time of data collection the weather was mostly rather cold. Reinhard Wittenberg and colleagues (2012) tested the effect of the weather on health and perception of heat for a subsample. During good weather periods the individuals rated general stress and heat stress in certain places such as the workplace or on public transport as less stressful than during cold periods. Thus, the actual weather has an impact on personal experiences and probably also on the results.

The sampling of the study limits the possibilities for analysis. Both city areas were disadvantaged in relation to heat exposure, though due to different reasons. While the city center warms up intensely during summer periods due to the dense and historic housing, which results in poor thermic conditions, the west side is enclosed by industrial areas. The research design did not allow the inclusion of a control group of an advantaged city district, as the study was restricted to two specific city districts that were the target of a federal project. Although the sample included two city districts with eight statistical areas that could have been further analyzed, the consideration of these regions did not bring additional insights. As the regions were rather heterogeneous, we controlled for the sampling region in the analyses. Future studies could deliver interesting insights when considering an entire city.

The results discussed in this article support results from other cities: the perception of heat stress depends on several individual factors of social vulnerability as well as specific housing conditions, which create more heat exposure and result in even more heat stress (Franck et al. 2013; Großmann et al. 2012; Pfaffenbach and Siuda 2012; Siuda et al. 2010).

Experiencing subjective heat stress has further implications: it affects the health status of a person and increases risk of mortality, as the heat waves in Chicago and Europe have shown. The results discussed here should also hold for other cities with similar building structures. Town and city planning must consider the impact of future climate changes on present city structures and start taking measures to cool down the air temperatures, for example, by increasing urban green spaces and green infrastructure (Franck et al. 2013; Jorgensen and Gobster 2010; Umweltamt 2012), as well as by implementing measures such as heat warning systems for socially vulnerable groups (Heudorf and Schade 2014).

Acknowledgments

I thank Dr. Andrea Knecht and Dr. Reinhard Wittenberg very much for their initiation of and cooperation in the project. I am also sincerely grateful to the anonymous reviewers for their critical and valuable remarks and comments on earlier versions of this article.

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Notes

1. This article refers to individual subjective heat stress, which can be measured by self-assessment on a Likert scale, as opposed to objective generalized measures for perceived heat or *perceived temperature*, which are based on a so-called complete heat balance model for a chosen average person (the Klima-Michel model), comparing the temperature of a reference environment to the actual conditions. It accounts for a larger number of people under standardized environments being outside and behaving normally (Jendritzky et al. 2000).

2. An (urban) heat island occurs in cities where one area develops higher temperatures than the rural surroundings. The solid material used to build roads or houses heats up more compared to areas of nature. The increase in temperature in certain areas is called a "heat island" (EPA n.d.).

3. The analysis focuses on explaining determinants of heat stress; the specific living contexts are of special interest, but not the districts themselves. Within the sampling design no control group was included; therefore, in the analyses the district was included as a control variable only.

4. Respondents whose telephone number was available via Internet research and telephone books were contacted via the CATI mode. A selection bias is possible, as younger people are less willing to publish their telephone numbers in a telephone book and the total number of younger people who use a conventional phone network is decreasing (Häder and Glemser 2006). A structural mixed-mode design combining CATI, PAPI, and even online surveys for data collection could reduce selection bias and increase response rates (Krug et al. 2014).

5. The overall measure on self-assessed subjective heat stress seemed here to be the best measure to analyze the general impact on individual life situations.

6. The dependent variable is actually an ordinal variable with ten values. A constant increase of heat stress across the scale is assumed; therefore, applying a linear regression model seems adequate. The final model was proven with instruments on regression diagnostics (for further details on diagnostics for linear regression models, see Ohr 2010).

7. The respondents were divided into four groups (along the quartiles), comparing young adults finishing their education, starting families, and in the early employment phase, people in the mid-employment phase aged 36–55 years, those in late employment through retirement aged 56–70 years, and older people of 71 years and above.

8. Using the measure of subjective health did not seem useful here, as it is an overall measure for health and also includes mental health factors such as stress. Therefore, heat stress could be considered part of health.

9. Bivariate analyses show that an increase in age leads to significantly more difficulties when climbing stairs. Age and physical health problems are not significantly correlated in a bivariate perspective.

10. Multiple imputation methods were used to impute the missing values of income. Available indicators of the socioeconomic situation (education, employment status) and variables that are known to determine personal income (gender, age, family status, having children) were used to replace the missing values of income.

11. For international comparison: “lower (secondary) education” is comparable with the International Standard Classification of Education (ISCED) code 2, “middle education” is comparable with secondary education, ISCED code 3, and “higher education” is comparable with tertiary education, ISCED code 5.

12. Few houses have more than four levels in Nuremberg.

13. Traffic noise was measured in decibel. Traffic noise during the day and night was presented for each address in noise maps at the website http://nürnberg-aktiv-gegen-lärm.de/vorschlag/wo-ist-es-laut (accessed 15 August 2014).

14. The statistical software Stata has a tool for geocoding. From initial addresses the geographical codes “longitudes” and “latitudes” were generated (Ozimek and Miles 2011). Open green spaces and park area codes were also included in the data set. Via Stata13, the geographical distance to each park center or access to the green space at the river Pegnitz was included in the data. The geographical distance to each point was calculated. The minimal distance to the next green space was included in the analysis to generate another objective measure of the green context of the respondents.

15. The street information and geocodes were separated and deleted from the data. Only the rough categories of district (Table 1) and distance measures were kept for the analyses, thus ensuring anonymity.

16. An interaction for climbing stairs and age as well as one for health status and age was included in the model. The inability to climb stairs in the different age groups showed no significant effects; therefore, only the main effect of stair climbing was included in the model.

17. In a bivariate correlation, income was significantly negatively correlated with heat stress, although this correlation diminished when other factors were taken into account. Several different models were estimated concerning the income variable. The reported model includes the income variable with imputed values via the educational level of a person. Models with multivariate imputation for income and models without income were also estimated. All three models led to the same results, with slightly varying levels of significance. Using the original income variable with missing values led to almost the same results, but fewer cases.

18. Results not shown in a table.

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Appendix: Descriptive results of the variables

Variable	N	Mean	Std Dev	Min	Max
DV: Heat stress	1155	4.85	2.48	1	10
Gender (1 = male)	1176	0.42			
Age in categories:					
18 to 35 years	299	0.26			
36 to 55 years	285	0.24			
56 to 69 years	290	0.25			
70 and older	290	0.25			
Level of education:					
lower (ref.)	260	0.23			
middle	314	0.28			
higher	545	0.49			
Monthly net income	932	1803	1354	5	10000
Employment status					
(1 = full-time)	1142	0.39			
(1 = part-time)	1142	0.09			
Having children (1 = yes)	1134	0.51			
People living in the household:					
one person (ref.)	464	0.41			
two	477	0.42			
three and more	184	0.16			
Family status (1 = alone)	1130	0.47			
Health difficulties when climbing stairs (1 = yes)	1160	0.44			
Health difficulties in the last 4 weeks (1 = yes)	1046	0.47			
Frequency of meeting:					
once a month or less (ref.)	133	0.12			
a couple of times per month	193	0.17			
weekly	244	0.22			
more than once a week	458	0.40			
daily	106	0.09			
No. of contacts	1110	11.82	9.26	0	50
Square meters of housing	1141	78.23	3.75	8	324
Floor level					
basement or ground floor (ref.)	199	0.17			
1st floor	255	0.22			
2nd floor	269	0.23			
3rd floor	233	0.20			
4th floor or higher	200	0.17			
"Outside option" at house (1 = yes)	1148	0.71			
Percieved distance to park area or greenery in minutes	1144	7.20	6.24	0	40
Use of green areas:					
never or seldom	317	0.28	0.45		
monthly up to weekly	370	0.33	0.47		
more than once a week to daily	396	0.35	0.48		
Traffic noise—daytime (1 = more than 45 db)	1176	0.76			
Green in front of the house (1 = little up to a lot of green)	1176	0.36			
Street type:					
big street (ref.)	300	0.26			
small street	661	0.56			
pedestrian area	215	0.18			
Green backyard or garden (1 = yes)	1176	0.61			
Distance to park area in meters	1176	0.65	0.26	0	1.296