Heat in the streets

Nimish Biloria[1], Leena Thomas[2], Pezhman Pakdel[3]
[1] University of Technology Sydney, Australia
Nimish.Biloria@uts.edu.au, 0000-0003-3152-5187[1], Leena.Thomas@uts.edu.au, 0000-0003-0707-9260[2], Pezhmanpakdel@hotmail.com[3]

Abstract: Heat stress from rising temperatures in the workplace is an urgent public health issue. The absence of canopy cover, excessive built-up areas with heat-reflective materials such as glass facades and concrete paving, the absence of shade provided by surrounding buildings, the width of streets, and traffic occupancy often aggravate heat stress in cities. This paper presents the outcomes of a research study to map, analyse, and visualise the lived experience of climate-exposed outdoor workers. The project sought to understand how experience data of heat-exposed urban workers can be communicated using digital tools and environmental sensors to derive evidence-based suggestions for developing heat-sensitive urban environments. Focusing on bicycle delivery couriers and outdoor council workers, the project draws on quantitative (temperature, humidity, and geo-location) and qualitative data (time worked and psychophysiological responses to heat) from outdoor urban workers. Minnow sensors, Strava (geo-location mapping), analogue intake and exit interviews, Google Street View, and online surveys were deployed for data acquisition, correlation, and prototyping of a real-time updating digital dashboard that served as a visual narrative of summer heat stress experienced by Sydney's essential outdoor workers. The dashboard is instrumental in revealing heat stress hotspots and corresponding opportunities for urban interventions (e.g., heat refuges, shade, landscaping) to mitigate urban heat effects while simultaneously revealing the lived experience data of the participant outdoor workers. A citizen science initiative, the research is instrumental in communicating the impact of the spatial, social, and policy landscape on critical climate emergencies to a broader audience.

Keywords: Heat stress; Vulnerable population; Qualitative and Quantitative research; Digital dashboard.

1. Introduction

At the time of writing, the publication of the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2023) IPCC report and recent heat waves in the northern hemisphere (Copernicus Climate Change Service, 2023 Zachariah et al., 2023) reinforce the reality that climate change is already resulting in extreme heat events with concerns and has grave consequences for human mortality and morbidity as well as serious impact to society livelihoods and economies. Based on similar predictions for the future here in Australia and experience (Hill, Cumpston and Quintana Vigiloa, 2021), the question of heat stress and urban heat remains extremely relevant for the Australian context.

Against a backdrop of concerns about rising temperatures and urban heat, Zander et al. (2015) conducted studies in Australia focusing on heat stress, work, and productivity. They found major threats

Sustainability and Health: the nexus of carbon-neutral architecture and well-being: 56th International Conference of the Architectural Science Association 2023, M. Dewsbury, D. Tanton (eds.), pp. 318 - 330. © 2023 and published by the Architectural Science Association (ANZAScA).

for many occupation classes. Climate heat is now recognised as posing 'immediate and pressing risks' for Australia (Stanley et al., 2017). In 2011, Hanna et al. addressed physiological impacts and policy responses and pointed to the need for more qualitative work. Qualitative research on the issue remains relatively weak. An important exception is Xiang et al. (2016) qualitative study in South Australia, which found that 30% of people working outdoors had experienced heat-related injuries (37% had experienced 'heat illness'). With no minimum national standard to address heat illness, the research found that only 20% of employees stated that work would cease when the temperature exceeded 40°C. Half of those surveyed had concerns about extreme heat and strongly favoured training, regulation, and workplace changes to address the problem.

Heat stress is an important factor in working conditions indoors (A.Y. Jia, D. Gilbert and S. Rowlinson 2018.) and outdoors. A substantial body of public health, industrial relations and occupational health and safety research reveals direct connections between working arrangements and worker health and safety outcomes (Quinlan, 2013). There are wider concerns about livelihood and productivity, with agriculture most clearly affected (Gornall et al., 2010; Kjellstrom et al., 2016). Insecure and underpaid outdoor workers are likely more vulnerable to heat stress than counterparts with better employment conditions. One US study found heat-related fatality 20 times more likely in the agriculture industry than in other sectors (Jackson and Rosenberg, 2010). Workers in these sectors are often self-employed or on piecework, and heat stress impacts livelihood and health.

Strong linkages exist between heat stress and the built environment regarding how cities are planned and constructed (Petkova et al., 2014; Smith and Levermore, 2009; Bulkeley et al., 2016). Exposure to heat is heavily stratified both across workplaces and in social contexts (Harlan et al., 2008). Reliance on home or work air conditioning and private transport can shape expectations for upper echelons; those unable to afford home cooling, who work in outdoor occupations and are dependent on public transport, can be much more exposed and, at the same time, more vulnerable. Inequity at the social, spatial, economic, and work flexibility front equally shapes our experience of heat stress. At the macro level, the emergence of satellite cities with large distances across suburbs only exacerbates exposure (Stone et al., 2010). Urban planning is also significant at the 'micro' level, such as access to water fountains and shaded and cooled resting spaces, preferably with foliage (Norton et al., 2015). Addressing such issues can be central to ensuring sociality in the city, enabling the city's connectivity and cultural vibrancy.

Within this context of heat stress, the paper presents the findings of the 'Heat in the Streets' research project funded by the City of Sydney in 2019. The project aimed to understand how the lived experience of heat-exposed urban workers can be collected, analysed, and communicated using digital tools and environmental sensors to derive evidence-based suggestions for developing heat-sensitive urban environments. The paper intends to provide urban planners and designers with evidence-based suggestions on developing contextually embedded heat-sensitive urban environments, subsequently enhancing accessibility and participation to and in the urban open spaces by the wider public, especially by outdoor urban workers. The research accordingly investigated the perspectives of heat-exposed workers on how infrastructure planning in the city, alongside workplace policies, could be improved. Heat-exposed workers as a vulnerable demographic were particularly chosen since their nature of work enables them to experience and reflect upon urban attributes such as the absence of tree canopy cover, excessively built-up areas with heat-reflective materials such as glass facades and concrete paving, the absence of shade provided by surrounding buildings, the width of streets, and traffic occupancy in certain urban zones of the city.

2. Methodology

The research primarily intended to create a participatory platform for gathering data on heat stress while adopting a citizen science methodology where participants socialise their experience of heat stress in a bottom-up, evidence-based manner. Citizen science resources such as citizenscience.org, citizensciencealliance.org, citsci.org and the 'Commons Lab' (Bonney et al. 2014; Bates et al. 2016) were referred to during the formulation of the citizen science-driven methodology. The research meticulously focused on mediating scientific data and participant experiences (Hochachka et al. 2012). Motivating participants to participate and making engagement accessible and simple via electronic devices based on common templates and interfaces were some of the mediation strategies involved in the project.

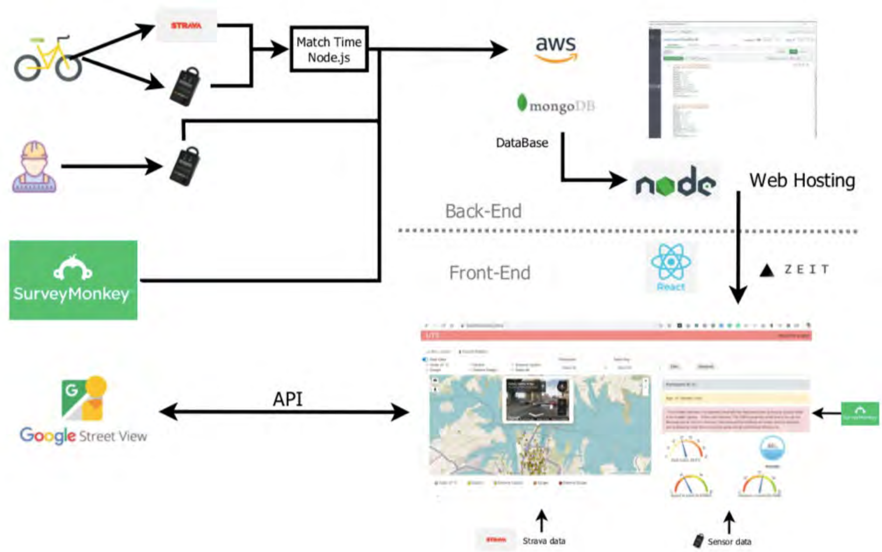

Figure 1 System architecture underlying the research.

Figure 1 illustrates the overall system architecture developed for the research and outlines the back-end computational processes (outdoor urban worker data collection using specific hardware and software, time-stamps-based data assimilation and data filtering, database development and web hosting), and front-end data visualization (Google street view and digital dashboard). Components comprising the system architecture are elaborated upon in the following sections:

2.1. Recruitment of urban workers

Urban workers, typically exposed to urban heat while conducting two distinct categories of work, are engaged in the study as citizen scientists:

- Workers in ongoing work for a government body (council outdoor workers): Six workers from the Parks Maintenance Unit in the City of Sydney and one worker from the road maintenance unit were identified to participate in the study.

- Gig workers working as subcontractors (bicycle delivery couriers): Eleven participants, eight document delivery courier workers and three food delivery workers, were recruited via a Facebook group for Sydney bike couriers.

2.2. Tools for Quantitative and Qualitative data collection

- Quantitative data: Heat stress data for each participant (bike couriers and council workers) was collected using a temperature and humidity data logger, namely, the Minnow Sensor 1.0 (Figure 2 - left). Minnow 1.0 offers accurate and repeatable logging for temperature and humidity. The device measures temperature to an accuracy of +/- 0.3 degrees centigrade over 5 - 60 degrees centigrade range and humidity to +/- 2.0% over the 20-80% humidity range. The geolocation of the participants is tracked in real-time using the Strava application (Figure 2 – right). Strava is a free social fitness application primarily used for tracking dynamic fitness activities such as cycling and running using mobile networks' GPS data.

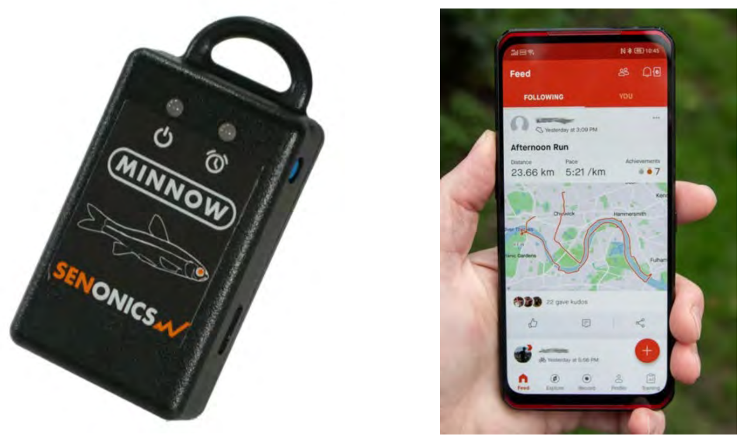

Figure 25 Minnow Sensor 1.0 is used for temperature and humidity data (left), and the Strava application (right) tracks geo-location in real-time during on-field investigations.

- Qualitative information pertaining to the amount of time worked and physiological responses to heat, including a post-activity reflection, are captured via a five-minute survey using the SurveyMonkey application installed on each participant's mobile phone. Additionally, intake interviews, as well as exit interviews, were conducted with each participant to extract their subjective opinion and mitigation suggestions as regards heat stress. As a precautionary measure and as a nudge, both groups of participants were sent a text message prompting them to complete the survey about their experience of heat stress during mid-day. Participants were additionally sent an SMS the evening before each day reminding them to carry their Minnow sensors during work hours. Bike courier riders were also instructed to log in to their Strava application (on their mobile phones) while performing their job.

2.3. Data collection

As a pilot initiative, five hot days (identified via BoM environmental predictions) during March 2019 were selected to deploy and collect heat stress sensor data, Strava-based location data, and SurveyMonkey-based experiential data. Intake and exit interviews were conducted on-site, transcribed, and stored on secure cloud storage.

2.4. Back-end and front-end computing

Amazon web services and a MongoDB database store data collected from the Minnow sensors, Strava, SurveyMonkey, and transcribed interview sources. The disparate data sets were cleaned and filtered before database storage through a custom program developed using Node.js. OpenStreetMap (OSM) is used specifically as the underlying map layer in the dashboard's front end, on top of which heat stress-related geo-location data is plotted in conjunction with the integration of panoramic Google Street View.

3. Research Results

3.1. Digital heat-stress data visualisation prototype platform production

A prototype digital platform for indexing, analysing, and visualising quantitative and qualitative data sets collected during the research term was developed to intuitively communicate quantitative and qualitative aspects of heat stress. The data relating to heat stress measurement and geo-location were collected in addition to the digital survey and physically conducted interviews. The role of the dashboard was thus to aggregate the collected datasets and visualise all associated parameters relating to the experiences of each participant. These parameters included Temperature and Humidity to derive the Heat Index (a measure of how hot it feels when relative humidity is factored in with the air temperature (https://climate.ncsu.edu/climate/heat_index_climatology), the speed at the point of the collected measurement and the distance covered by the participant at the point of the acquired reading (for bike couriers). Besides this, salient features extracted from the interviews about the perception and experience of urban heat and how the workers cope with the same are also displayed (Figure 6). This adds a qualitative dimension to the otherwise quantitative datasets and enables comparison of on-ground environmental conditions with the participant's lived experience.

3.1.1. Data extraction

Both temperature and humidity were logged at a user-configurable logging rate (set to a reading rate of 1 minute in the case of this study), via a PC application program: Sensonics. Raw data relating to temperature and humidity was registered in the Sensonics platform and was automatically converted to a CSV file format for ease of transfer to a custom Mongo database through a custom program written in Node.js.

Bicycle Courier participants were instructed to download the Strava application and log in using accounts created for this research. Each participant’s recorded log was geo-spatially mapped using OpenStreetMap (Figure 3). These data sets are downloaded directly from the respective Strava accounts of each of the participants as GPX files. A custom program written in Node.js eventually extracted and transferred the geolocation and associated datasets to the custom-made Mongo database.

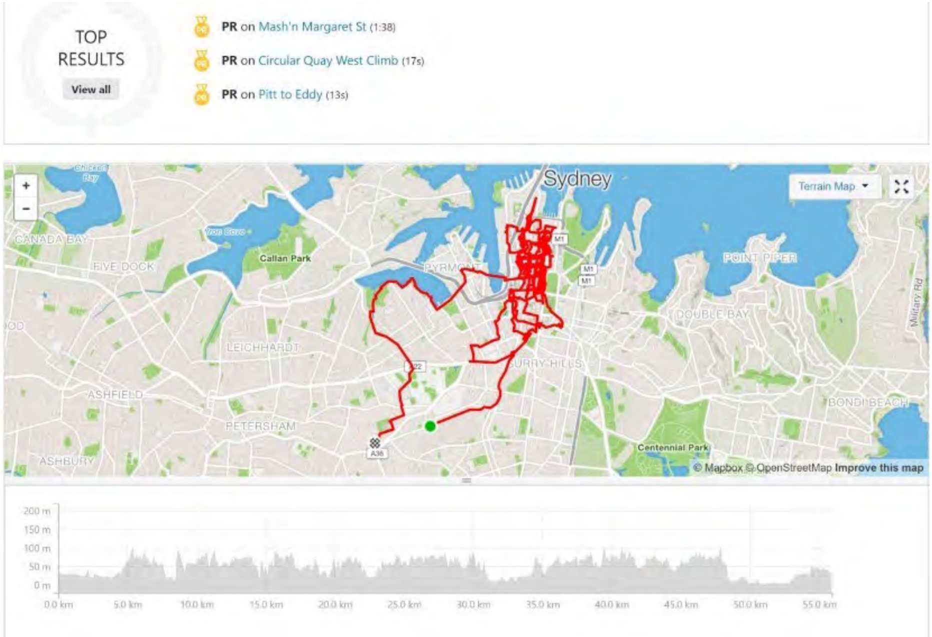

Figure 3 A screenshot from the Strava website showcasing geolocation and associated time segment (point-to-point) data plotted on OpenStreetMap.

3.1.2. Data filtering and correlation

An algorithm was further developed to extract matching data entries between Strava's geolocation data and the Minnow sensor's heat stress data. Data was obtained from both collection sources and was filtered with respect to time, date and participant id. The matching sets of heat stress and spatial data were subsequently stored in a custom MongoDB database developed for this research.

3.1.3. Data visualisation

The prototype digital dashboard visualises the correlated datasets in two distinct sections (Figure 4) with an operating menu bar at the top of the dashboard window. The menu bar allows intuitive navigation and selection of the following:

- Selection of participant type: Bicycle Couriers or Council Workers
- Selection of the Heat Index caution level
- Selection of individual participants and the day the data had been recorded.

Activating the Filter button after making the aforementioned selections results in the display of relevant data. Besides this, a Download option is also provided to extract the chosen selection-based data in an Excel worksheet format. A provision to see the plotted heat stress data in full screen is also made available in the dashboard (Figure 5). Below this section, a provision to visualise the Heat Index value per participant plotted in relation to the day of the selected data is made.

The primary visualisation section below the menu bar is divided into two halves: the left half displays a geospatial mapping of the filtered and correlated datasets. The matching data is plotted using OpenStreetMap in the dashboard's geospatial visualisation section. The visualisation is in the form of Heat Index plots at an interval of 5 minutes on the route taken per bike courier. The colour variation in these plots reflects heat-index caution levels (Figure 4). The right half of the screen is a real-time feed from the survey completed on the day, showcasing quantitative responses and open-ended, lived-experience-based comments.

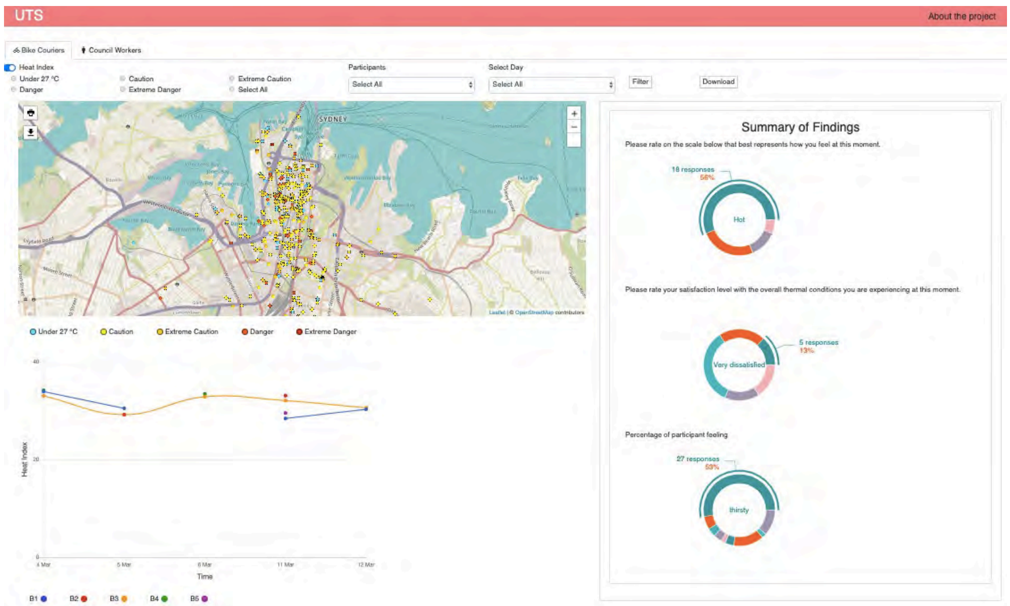

Figure 4 Screenshot of the Dashboard Front-end with the Menu bar on top and two distinct Left and right data visualization sections.

Each plotted Heat Index point (in the OpenStreetMap section) can be clicked to activate a Google Street View pop-up window of the location to reveal the 3-dimensional nature of urban space in the immediate vicinity of the geolocation. This helps determine aspects such as the amount of tree cover, the height, material, and nature of buildings that could shade or produce heat in the streets, traffic conditions, land use, permeable vs. impermeable surfaces etc., at that location (Figure 6 Left). Furthermore, clicking on any participant data opens an interactive visual mapping of the Heat Index Reading progression compared with the actual Temperature changes for the chosen day.

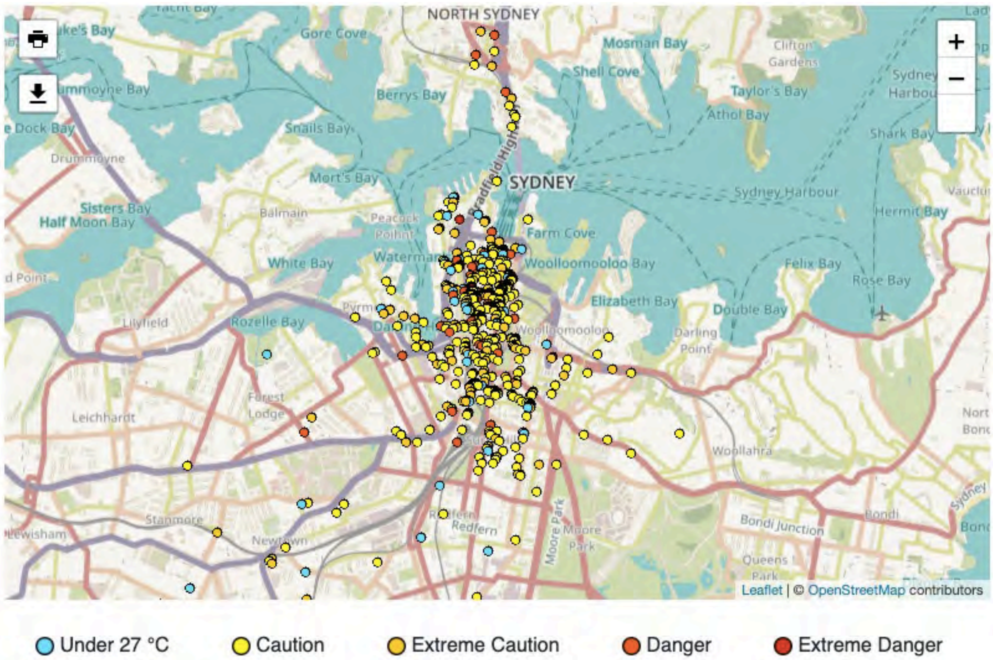

Figure 5 Left: Screenshot showcasing Google Street View corresponding to the selected Heat Stress Point Right: Screenshot of the right data visualization panel showcasing qualitative and quantitative datasets of a participant.

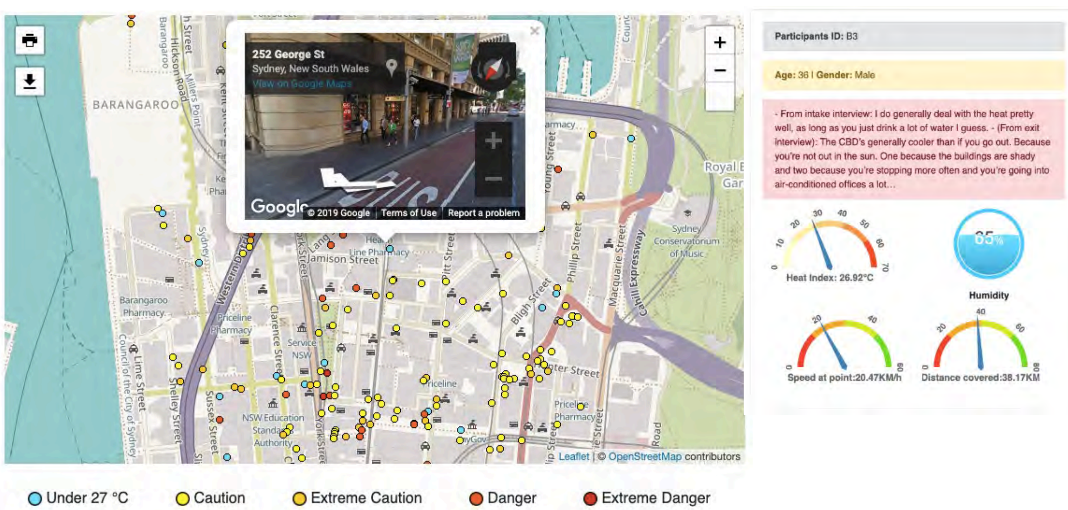

Figure 6 Screenshot showcasing Heat Index visualization on geolocated datasets of all participants on a given day and time interval.

The right side of the dashboard is coded for additional information display: In the home page view, the right side of the dashboard pane displays information graphics summarising the qualitative feedback (pertaining to experienced responses to thermal conditions, physiological response, and overall perception of temperature conditions during the term of the research) provided per participant. This data is collated from the survey forms and is based on the responses provided by actual participants in the study. Selecting a participant from the menu bar transforms the visual display on the right pane and showcases data relevant to the chosen participant: Participant ID, Survey data (quantitative and qualitative), excerpts from any interview conducted with the participant, Heat Index measurement and humidity measurement (Figure 6 Right).

3.2. Multi-domain research deductions

With its integrated quantitative and qualitative data correlation and visualisation ability, the digital dashboard prototype served as a rich platform for extracting multi-domain deductions contributing to urban heat stress. Initial data comparison demonstrated the well-established nexus between outside temperature/ humidity and work effort in producing heat stress. For ease of comprehension, the multi-domain deductions are categorised as follows:

3.2.1. Public health deductions

Psychophysiological impacts: Through the SurveyMonkey survey, it became apparent that heat stress had a similar impact on bike-courier and council workers. Almost half of all respondents stated they experienced heat stress at work, with three-quarters acknowledging they felt thirsty. A quarter to a third of bike-courier deliverers and council workers also felt overly fatigued, resulting in difficulty concentrating, and subsequently faced trouble completing assigned tasks (including a small proportion experiencing fainting or dizziness). Differences between how the two user groups attempt to mitigate heat stress became apparent from the salient feature extraction section of the dashboard. Two-fifths of the courier delivery workers resorted to extra breaks during hotter conditions; three-quarters of the courier delivery workers rehydrated more often; 10% had taken on lighter duties; and 4% stopped work. Only a fifth of the Council workers had taken extra breaks; two-fifths had otherwise changed how they did their work or where they worked; almost all Council workers rehydrated more often; 15% undertook lighter duties, and 9% stopped work. This inherent flexibility in how and when work is conducted during hotter conditions must be considered and translated into public health and wellbeing policies.

3.2.2. Policy deductions

Workplace policy: Exit transcribed interviews showed that the flexibility in work scheduling allowed council workers to reallocate the most physically exerting tasks. However, even though the bike delivery couriers could take more breaks (between deliveries), they could not take on lighter tasks due to their work schedules' non-flexible nature. Work policy for such vulnerable gig-economy workers thus needs to be revisited, and collaborative solutions involving private organisations, worker unions, and public policymakers need to be initiated accordingly.

Urban context and design features: Courier delivery workers, when provided with the opportunity to plan routes autonomously, took advantage of the available infrastructure of the city to mitigate the impacts of heat. Reported strategies included choosing to work in the CBD, where streets were shaded by the tall buildings in the middle of the day, or finding refuge in air-conditioned lobbies, cycling along tree-lined streets, or relegating strenuous or inclined routes to cooler parts of the day. Other key factors determining the choice of routes were the presence or absence of dedicated bicycle paths, the amount of congestion, and traffic density at different times of the day. Policies regulating the provision of supportive infrastructure, such as cycling routes, water fountains, tree canopy, etc., should be integrated and communicated with urban planning and development bodies.

3.2.3. Data deductions

OpenStreetMap-based plotting of heat index: The colour-coded plotting of heat stress in combination with the Google Street View images allows one to correlate the physical features of the built environment, such as the height, material, and density of the built fabric, the nature of surfaces (permeable vs. non-permeable), the nature of urban green (tree canopy, sky view), the nature of the activity (traffic flow, pedestrian flow, land-use), self-shading (building's shadows). For instance, in Figure 6, the blue plot depicts a temperature of under 27 degrees Celsius, even with the absence of tree cover and heavy traffic can be attributed to the degree of self-shading created by the proximity of high buildings, the non-reflective nature of the stone surface of the surrounding buildings, and the additional sun-shading enclosures. The nature of surfaces is, however, impermeable and could certainly be improved by adding urban green as a mitigation strategy for further heat reduction. Integrating three-dimensional visualisation of the urban context alongside two-dimensional statistical data is thus considered to add value while helping otherwise siloed domain-specific (transport, health, urban planning, environment) interpretations of tackling heat stress in the urban environment.

3.2.3. City council deductions

Lived-experience-driven advice to local councils: The lived-experience-based results from the research gathered irrefutable evidence-based data and can serve as a vital channel for communicating on-ground user needs to respective city councils. Exit interviews gathered valuable suggestions about how the council could minimise heat stress: sufficient infrastructure provision and adequate maintenance in the form of access to cold water, the introduction of working bubblers, and clear communication of public water access points across the city. Council workers suggested workplaces provide hydrates for mitigating humidity, non-polyester clothing, and roofing for shading on ride-on machines. Courier delivery workers suggested increasing natural and artificially produced shading on streets and rest areas, including installing water misters in specified public areas. Additionally, the provision of dedicated cycling lanes, a call to educate drivers and the use of slip-proof paint for cycleways were suggested to improve infrastructure quality. These are quintessential bottom-up feedback from the everyday citizen that could enrich the urban environment and positively improve health and wellbeing.

4. Conclusion

The project aimed to combine a citizen science approach to understanding the impacts of heat stress on heat-exposed urban workers with data analysis and visualisation techniques to create a digital platform for communicating the lived experience of such a vulnerable demographic. The digital platform and the underlying system architecture can process and visualise multiple forms of qualitative and quantitative data capable of data filtering and producing data correlation-driven informative visuals pertaining to various aspects of heat stress experienced by the participants. The prototype platform is fully scalable and can drill down to an individual participant level to extract personalized heat stress-related contextual determinants. Besides this, the ability to spatialize the received data alongside embedding Google Street View imagery per geospatial heat stress point allowed the information to become easily accessible and comprehensible to a larger audience while allowing one to study the determinants of heat stress in a contextually embedded manner.

The prototype can be further refined to stream real-time data that can be made freely available to view by city councils and residents alike. The platforms could also be enriched by developing a mobile application version built on the same platform footprint wherein survey forms, note-taking and commenting, and geolocation are combined into one seamless package. It would also be possible to integrate real-time temperature and heat stress data at fixed points within the city through smart poles/bus stops, etc. A network of such sensors (IoT devices) would allow for the development of a temporal understanding of key places of interest — public parks, public spaces, bus stops and other areas where citizens are exposed to the vagaries of climate.

The research also demonstrated the well-established nexus between temperature, humidity, and work effort in producing heat stress. The capacity to minimise exertion during the hotter times of the day and allocate work requiring more effort during cooler days/times can be critical. The research findings also suggest the importance of workplace autonomy in determining the pace and type of work, thus shaping the experience. Besides this, the role of the built environment, especially mitigation-focused urban infrastructure development such as providing cold water, bubblers and misters at strategic locations, tree canopy and shading, dedicated cycling lanes etc., was brought to the fore via this evidence-based citizen-driven research.

Overall, the research successfully prototyped a digital tool for communicating the lived experience of heat-exposed urban workers. In doing so, multiple mitigation strategies ranging from flexible work policies, urban infrastructure, lived-experience-driven advice to local councils, and a reflective evaluation of the potential and possible development of the prototype were bought to the fore.

5. Acknowledgements

We want to acknowledge the courier delivery and council workers who participated in the research and unbiasedly shared their lived experiences with the research team. We would also like to acknowledge the City of Sydney Council for extending the City of Sydney research grant towards this project and creating opportunities for networking with various city council departments, which subsequently led to the participation of outdoor council workers.

6. Research ethics

The University of Technology Sydney Human Research Ethics Committee granted research ethics for the project (UTS HREC ETH17-1817).

7. References

A.Y. Jia, D. Gilbert S. Rowlinson (2018) Seasonal Patterns of Thermal Stress in the Work Environment of Construction Workers in a Megaproject in Australia, ASA Conference, RMIT.

Bulkeley H., Broto V.C., Edwards G.A.S. (2016) An Urban Politics of Climate Change: Experimentation and the Governing of Socio-Technical Transitions. Routledge.

Close Hill S, Cumpston Z, Quintana Vigiola G (2021). Urban: Climate change. In: Australia State of the environment 2021, Australian Government Department of Agriculture, Water and the Environment, Canberra. Available from: https://soe.dcceew.gov.au/urban/pressures/climate-change (accessed 15 August 2023)

Copernicus Climate Change Service (2023) The European heatwave of July 2023 in a longer-term context. Available from: https://climate.copernicus.eu/european-heatwave-july-2023-longer-term-context (accessed 15 August 2023)

Gornall J., Betts R., Burke E., et al. (2010) Implications of climate change for agricultural productivity in the early twenty-first century. Philosophical Transactions of the Royal Society B: Biological Sciences, 365(1554), 2973-2989.

Hanna, E.G., Tait, P.W., Sithole, B., et al. (2011). Heatwaves in Australia: risks and responses. Australian and New Zealand Journal of Public Health, 35(2), 197-203.

Harlan S.L., Brazel A.J., Prashad L., et al. (2008) Neighborhood microclimates and vulnerability to heat stress. Social Science & Medicine, 67(12), 1853-1863.

IPCC, 2023: Summary for Policymakers. In: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, pp. 1-34, doi: 10.59327/IPCC/AR6-9789291691647.001

Jackson L.L., Rosenberg H.R. (2010) Preventing Heat-Related Illness or Death of Outdoor Workers. Centers for Disease Control and Prevention.

Kjellstrom T., Kovats R.S., Lloyd S.J., et al. (2016) Heat, Human Performance, and Occupational Health: A Key Issue for the Assessment of Global Climate Change Impacts. Annual Review of Public Health, 37(1), 97-112.

Stanley, F.J., Vajdic, C.M., McMichael, A.J., et al. (2017). Climate change and health in Australia: impacts, projections and adaptation

responses. Asia Pacific Journal of Public Health, 29(2_suppl), 8S-14S.

Norton T.W., Lipschultz R.D., Kinney P.L. (2015) A human health perspective on climate change: a report outlining the research needs on the human health effects of climate change. Environmental Health Perspectives.

Petkova E.P., Vink J.K., Horton R.M., et al. (2014) Strategies to reduce the harmful effects of extreme heat events: a four-city study. International Journal of Environmental Research and Public Health, 11(6), 6110-6128.

Quinlan M. (2013) The impact of precarious employment on worker health in Australia: A comparative analysis with European Union countries. Policy & Practice in Health and Safety, 11(2), 53-70.

Smith S.J., Levermore G.J. (2009) The SAGE Handbook of New Urban Studies. Sage Publications Ltd.

Stone B., Hess J.J., Frumkin H. (2010) Urban form and extreme heat events: are sprawling cities more vulnerable to climate change than compact cities? Environmental Health Perspectives.

Xiang, J., Hansen, A., Bi, P., et al. (2016). Health impacts of workplace heat exposure: an epidemiological review. Industrial Health, 54(5), 389-400.

Zander, K.K., Botzen, W.J.W., Oppermann, E., et al. (2015). Coping with heat waves: an interdisciplinary review of knowledge gaps and recommendations for future research priorities. Environmental Research Letters, 10(12), 124007.

Zachariah, M., Vautard, R., Chandrasekaran, R., Chaithra, S. T., Kimutai, J., Arulalan, T., et al. (2023). Extreme humid heat in South Asia in April 2023, largely driven by climate change, detrimental to vulnerable and disadvantaged communities. Imperial College London. Available from: <Spiral: Extreme humid heat in South Asia in April 2023, largely driven by climate change, detrimental to vulnerable and disadvantaged communities (imperial.ac.uk)> (accessed on 10 August 2023)