H3Sensing: Mobile Sensing of Pedestrian Heat Stress

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Context and motivations:

The average temperature in France may increase between 0.6° and 1.3°C by 2050 [1]. Beyond 2050, even if estimates are less accurate, several scenarios predict a strong increase in the number of heat wave days by 2100 in France as well as maximum temperatures in the summer 6° to 13° above the historic maximum temperatures [2]. There is increasing evidence that extreme heat is associated with excess mortality and morbidity [3,4], in particular for elderly populations [5] and patients with pre-existing health conditions [6,7], posing an important burden on health systems [8,9]. The effects of temperatures on mortality tend to vary over space and time, in relation to the adaptation of local populations to heat [10]. In addition to an effect of high temperature on the same day, an added effect related to the duration of the heat wave was documented after as little as 4 consecutive heat wave days [10].

While 68% of the world population is expected to live in urban areas by 2050, urban settings are associated with a higher elevation of temperature during severe extreme heat events as compared to rural areas, which is referred to as the urban heat island (UHI) effect [11-13]. Temperature differences are even greater at night, reducing physiological recovery at night in urban centers. UHIs are associated with an amplification of heat health effects [13,14].

In addition to this overall UHI effect, intra-city variations in pedestrian thermal heat stress during heat waves are observed [15]. These very high variations are associated with changes in shading, materials, wind speeds as well as soil moisture and evapo(transpi)ration rates, e.g. as can be provided by urban green and blue spaces. Vegetation, presence of water, density of buildings, and presence of impervious surfaces in the vicinity influence local thermal environmental conditions during heat waves [16]. The architecture, materials, and colors of buildings and the configuration of dwellings also significantly contribute to thermal stress and discomfort in dwellings [17]. To address the complexity of how urban environments, buildings, and dwellings influence heat exposure and health, the "Heat waves, urban Heat islands, and wellbeing and Health: a mobile sensing approach" (H3Sensing) project brings together the expertise of epidemiologists (IPLESP, SIO), urbanists (APUR), and climate scientists (LIED).

Specifically, the project aims to survey the health, wellbeing and heat stress experienced by approximately 200 participants in the Grand Paris metropolitan area in late Spring and Summer, outside of and during heatwaves. In the context of the H3Sensing project, the LIED is tasked with developing, testing and equipping the participants with a wearable heat stress sensor kit. The proposed Tremplin Recherche project aims to contribute to the development and testing of this heat stress kit.

Objectives:

The student will contribute to developing and testing a wearable heat stress sensor kit that will be worn by the participants during the survey phase of the H3Sensing project. The wearable sensor kit aims to monitor heat stress conditions experienced by participants throughout their day over a survey period of 4 days. In addition, a fixed-position weather station with an indoor heat stress kit and solar irradiance sensor will be positioned in each participant's home for the duration of the survey.

To monitor heat stress conditions, the terms of the pedestrian energy balance must be measured (see Figure 1). These parameters directly represent the ongoing heat exchanges between a pedestrian and his/her environment (Sun, road and sidewalk materials, vegetation, building materials, …).

Typically, this requires air temperature and humidity as well as wind speed and radiant conditions to be measured with appropriate sensors. The constraints of wearability require lightweight instruments as well as power autonomy for the datalogger, all while still providing adequate reliability and measurement quality. To be successful, adequate sensor integration is also required in the wearable kit.

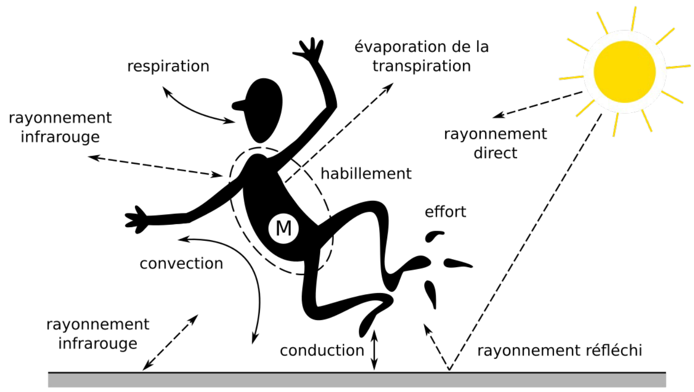

Figure 1: Pedestrian heat budget (adapted from Havenith et al. 1999)

Preliminary work has begun on a wearable backpack over the course of the 2021-2022 academic year. The student will continue work on the prototype of the wearable backpack with improved integration and power management as well as develop the fixed indoor weather station and solar irradiance sensor.

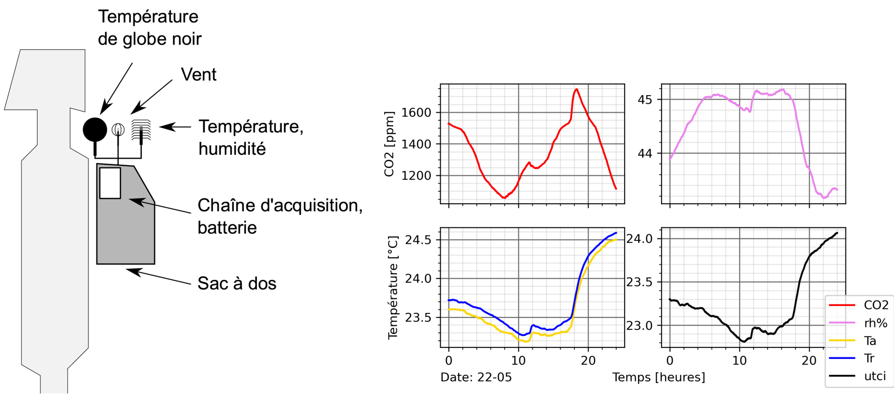

Figure 2: Diagram of wearable sensor kit (left) and preliminary data (right) (Bartoli et al. 2022)

This will include sensor integration as well as testing of alternative sensors, notably for monitoring the radiative environment. Most of the equipment required is already available at the lab and at the student's disposal.

The complete prototype will be tested in different environments, namely Paris and Milan (Italy) in partnership with colleagues at Politecnico di Milano working on the topic of outdoor thermal comfort and heat stress.

Skills required:

- Scientific curiosity and strong motivation
- Knowledge in heat transfer physics and/or skills in electronics for sensor integration
- Literature review
- Experimental skills (designing, testing and constructing prototypes)
- Data analysis and interpretation

Expected results:

- Prototypes (3):
  - Wearable outdoor sensor kit (backpack)
  - Indoor sensor kits: weather station and solar irradiance station
- Test protocols conducted in Paris and Milano (outdoor and indoor)
- Data processing and comparison

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