# DigitalExposome: Unravelling the relationship between the Environment and Mental Wellbeing

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## Introduction

The long-term exposure to urban environmental stressors such as particulate matter, gases and noise have been found to significantly impact an individual's behaviour and physiological health. The World Health Organisation (WHO) find that 91% of people are living in places where the air quality guidelines are not met and the use of non-clean fuels and household emissions in the atmosphere are causing over 4.2 million deaths each year.
Developments in urban sensing and Internet of Things (IoT) has created the possibility to utilise environmental and on-body sensing tools to monitor the environment and impact to individuals. Sensor-based technologies are increasingly popular due to their availability to collect data in real-time, affordability and small size.
Mobile technology in previous research coupled with sensors have aimed to provide a deeper understanding into the impact of exposure to an individual in a particular location.
Developed in 2005, the Exposome Concept (Figure 1) encompasses each exposure that is subjected to a human from birth to death.

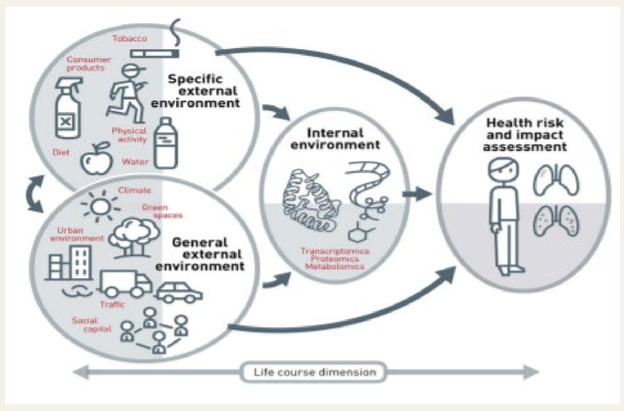


Figure 1. Demonstrating three stages of Exposome Concept

The concept in its current form can calculate some of the impact of environmental exposure, however, there remains some challenges. Most studies have found it challenging to address and understand Exposome fully because of its size, quantity of data required, and the overall quality of the data produced.

## DigitalExposome

DigitalExposome is a framework (Figure 2) to quantify an individual's exposure to the environment by utilising a range of technological, mobile sensing and digital devices. The concept aims to measure multiple environmental factors using mobile technologies and then quantify them in real-life settings. The combination of multiple data collection methods helps to support DigitalExposome and gain a better understanding into how exposure to the environment can impact mental wellbeing.

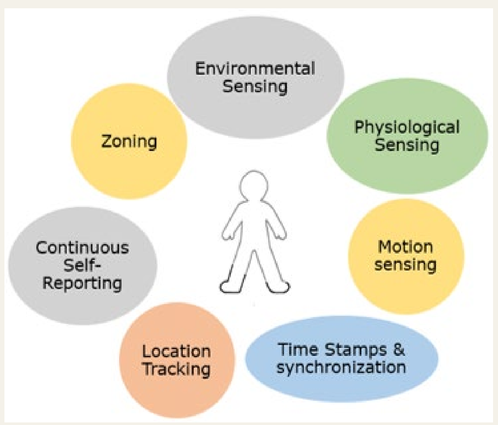


Figure 2. Data collection methods in unravelling DigitalExposome

DigitalExposome promotes the use of the Exposome concept by digitally providing a better understanding into the impact of exposure directly to an individual. There are many opportunities with this concept in exploring the link between pollution and wellbeing. The concept is primarily made up of two parts: data collection and data analysis. We see this as being a key part of the Exposome concept, where both terms are clearly connected through their vision of being able to capture the true exposure that an individual has been exposed to. Data that is generated through the use of technology, such as sensors is ideal to monitor various exposures and enable the possibility to link this to health.

### Conceptual System Architecture

Conceptual layer explains the four main areas that can impact mental wellbeing include environmental, biological, social and cultural factors. (See Figure 3)

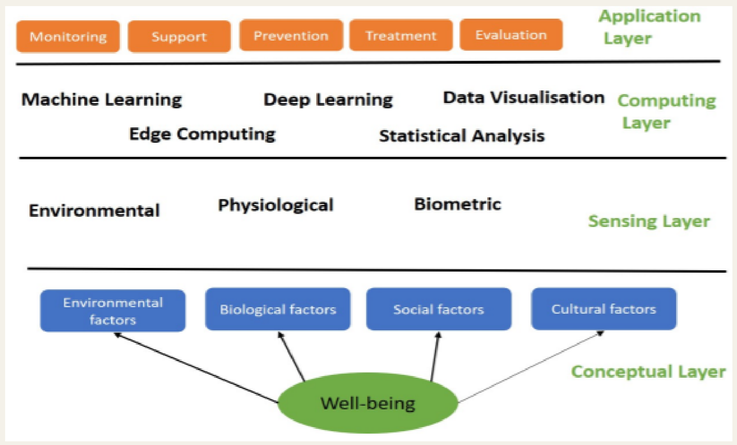


Figure 3. Conceptual and System Architecture of DigitalExposome

## Methodology

Participants walked through a range of different urban environments (see Figure 4) from several green to busy and polluted spaces which would help to demonstrate the impact of different levels of exposure to air pollutants.

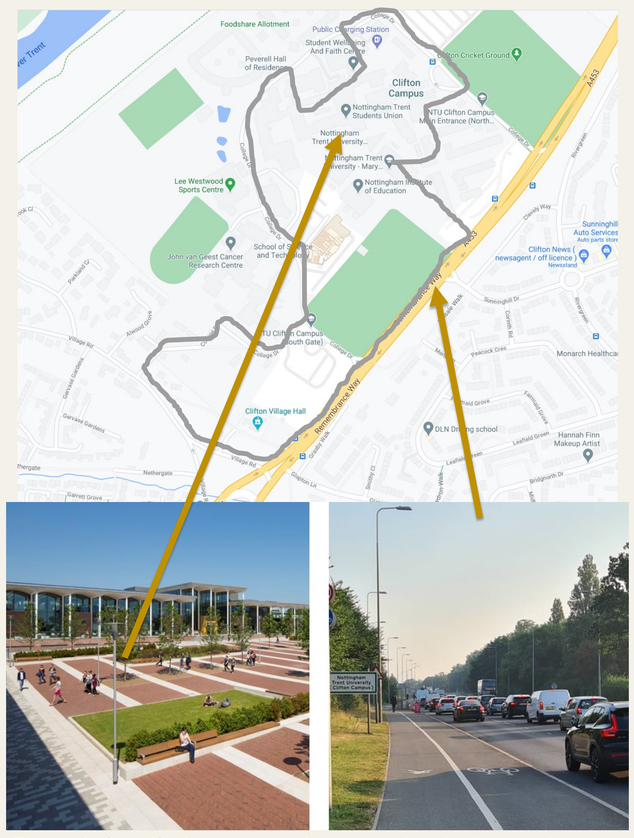


Figure 4. Specified route map demonstrating the two environment (left) Green spaces and (right) Busy, polluted

### Data Collection

Participants were given a custom-built smartphone app to record momentary wellbeing, E4 Empatica to observe physiological changes and Enviro-IoT to capture environmental pollution (Figure 5).

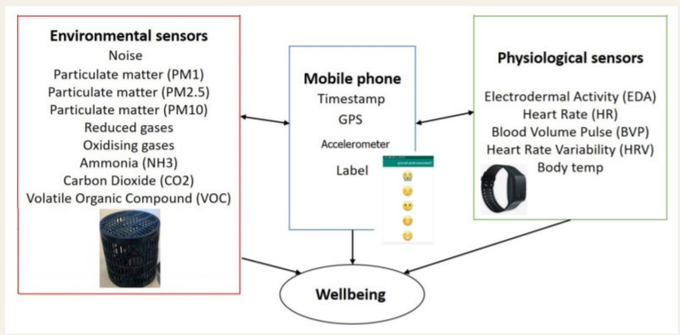


Figure 5. (left) Enviro-IoT, (middle) Wellbeing Application, (right) E4 Empatica along with collected variables

## Results & Discussion

Figure 6, demonstrates the impact of wellbeing against levels of PM2.5. The bars on the chart are associated with how many times a particular user would label how they were feeling (reported wellbeing) whilst walking around the environment. The results of this indicate that high levels of PM2.5 are associated with a negative wellbeing, shown by participants choosing '1' on the device. Whereas where participants labelled '5' (very positive wellbeing), the levels of PM2.5 were much lower.

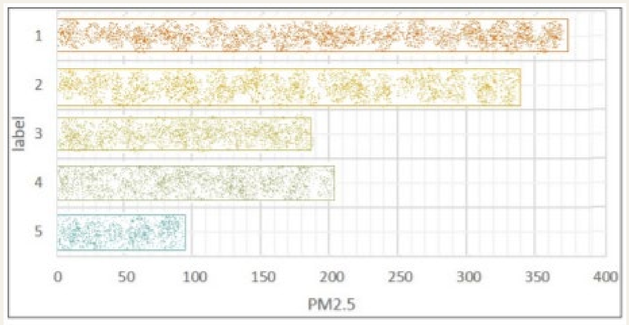


Figure 6. Depicts the relationship between the self-reported participant's wellbeing (label) and PM2.5

## Spatial Visualisation – Heat Maps

Heat maps are a common method in investigating patterns with collected sensor data. Figure 7, presents several environmental and physiological sensor data, depicting the changes in both while the participant is travelling around the route. At each right corner if the map we can observe that moving from a green space into a busy polluted space found an increase of PM2.5 and Noise which also resulted in an increase of Heart-Rate Variability (HRV) and ElectroDermal Activity (EDA).

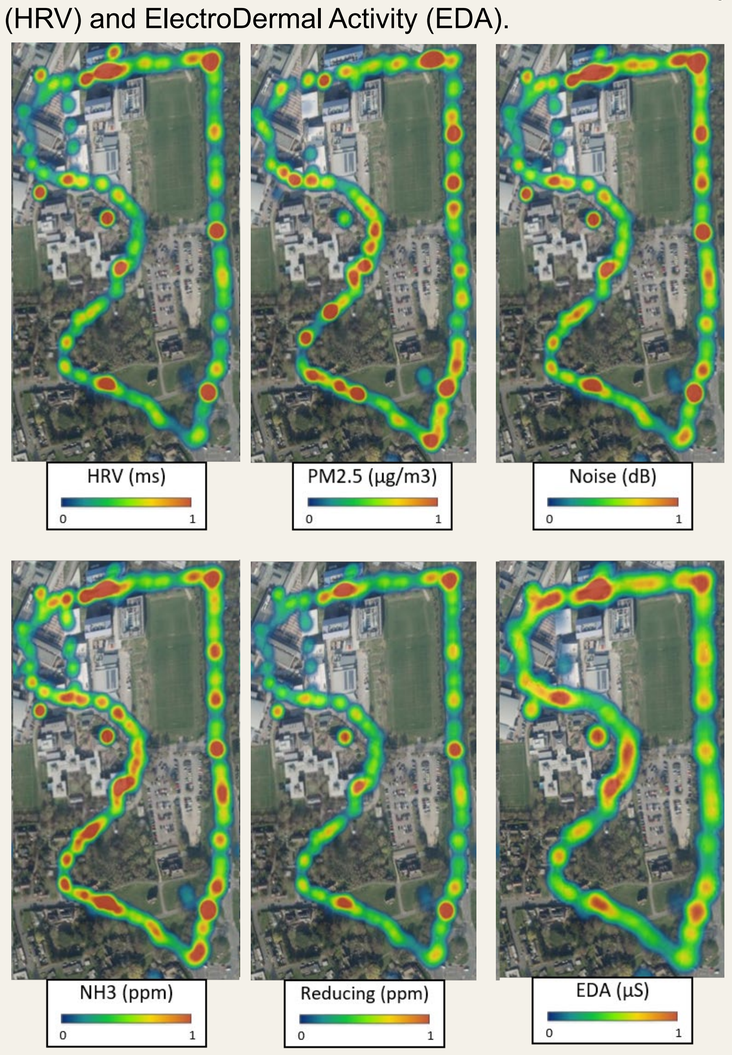


Figure 7. Several heatmaps demonstrating environmental and physiological sensors along the specified route

## Voronoi Visualisation

Figure 8, presents the self-reported momentary wellbeing data using the app on the specified route for this experiment. The colour of the polygons represents the wellbeing data from low negative to high positive. The visualisation demonstrates that poor wellbeing (lighter colour) was most reported along the main road where high levels of pollution were also experienced whereas more positive states of wellbeing was recorded in less polluted areas such as fields and open spaces.

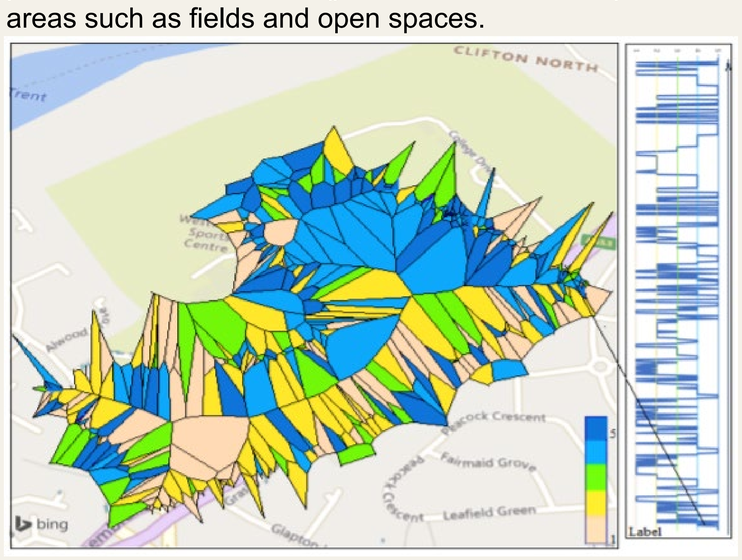


Figure 8. (left) Voronoi overlay from one participant data. Each polygon represents one location trace tagged with a wellbeing label while collecting the data in specified route (the map layer from Microsoft Bing), (right collected label data from start to end)

## Conclusion & Future Work

DigitalExposome that demonstrated the potential of employing a multi-model mobile sensing approach to unravel the relationship between the environment and it's impact on mental wellbeing. We found that physiological (on-body) sensor data is directly impacted to high levels of pollution (PM in particular) within the environment. In the future environmental sensors to observe changes that may improve our sense of places and characterize the relationship between people and spatial settings, which in turns might influence the future design of urban spaces.

**Find out more about this work:**

Johnson, T., Kanjo, E., & Woodward, K. (2021). *DigitalExposome: Quantifying the Urban Environment Influence on Wellbeing based on Real-Time Multi-Sensor Fusion and Deep Belief Network.*