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Engaging the Senses: The Potential of Emotional Data for Participation in Urban Planning

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Abstract: This paper presents an exploratory study on the potential for sharing urban data; one where citizens create their own data and use it to understand and influence urban planning decisions. The aim of the study is to explore new models of participation through the sharing of emotional data and focuses on the relationship between the physical space and emotions through identifying the links between stress levels and specific features of the urban environment. It addresses the problem in urban planning that, whilst people's emotional connection with the physical urban setting is often valued, it is rarely recognised or used as a source of data to understand future decision making. The method involved participants using a (GSR) device linked to location data to measure participant's emotional responses along a walking route in a city centre environment. Results show correlations between characteristics of the urban environment and stress levels, as well as how specific features of the city spaces create stress 'peaks'. In the discussion we review how the data obtained could contribute to citizens creating their own information layer - an emotional layer- that could inform a shared approach to participation in urban planning decision-making. The future implications of the application of this method as an approach to public participation in urban planning are also considered.

Keywords: emotions; participation; digital participation; physiological sensors; galvanic skin response; GSR; stress levels; emotional layer; urban

1. Introduction – Sharing Cities

A sharing cities approach focuses on bring local people together through shared activities and cooperation for the benefit of the city and includes initiatives such as carsharing, community currencies, cohousing, hackerspaces, timebanks and tool or kitchen libraries. These new forms of sharing, enabled by technological devices and platforms [1] work by enabling citizens to create, adapt and exploit data[2] and can create new ways in which citizens participate in the governance of the city. For example, civic apps, developed by citizens, civic organisations and commercial companies [3] have become widespread and typically create some form of two-way interaction where citizens contribute to commenting on or providing data on public services usually offered by the city such as crime prevention, rubbish collection, public transportation and pollution reduction. Mclaren and Agymen present as new model for collaboration and sharing around the city where "the same measures that enable sharing online, also – if civil liberties are properly protected – enable collective politics online. We see the increasingly blurred nexus between urban- and cyberspace enabling transformation – this time in the political domain. These spaces are fundamentally important for forms of participation invented and controlled by the people" [4]. This takes a model of participation, or sharing data that is termed 'co-production' whereby 'citizens perform the role of partner rather than customer in the delivery of public services' [5]. The challenge is how to enable citizens who are non-experts to gather, analyse and share data in a way that can meaningfully contribute to urban planning processes. The aim of this paper is to look at the potential of emotional data for enabling participation in urban planning, that contributes towards a shared cities approach. The objective of this approach to propose that a sharing emotional data can enable better insights of the city and its inhabitants which could lead to a citizen-centred approach in urban planning processes

In this paper we take the approach that sharing practices present an alternative model of participation in city decision making. Conventional citizen participation methods in city planning are typically linear and include referenda, public hearings, public surveys, charettes, public advisory committees or focus groups which often require the participants to be physical present at particular time and place (see Figure 1). The qualitative nature of data gathering and sharing means that citizens that have input into such consultations typically participate through methods such as completing surveys and contributing verbal comments, which are qualitative in nature and require further analysis to be used effectively. These forms of data are not easily translatable into the types and format of data and outcomes that are used by urban planners; such as urban plans, maps and GIS data. In addition factors such as the time required of citizens to participate often results in apathy among citizens [6], so that actual participation rarely represents a majority of inhabitants or involves the full range of stakeholders [7].

Figure 1. Current model of participation in Urban Planning process

Digital technologies can address some of the issues of participation in the urban planning process by enabling a more accessible system for the public to shape their neighbourhood's future [8]. Munster et al. outline potential advantages of digital participation which include the utilisation of wider pool of knowledge through broader audience and participants, which creates an interactive and communication-oriented planning process [9]. They can lower barriers for participation, involve a wider range of participants, and by enabling people to discuss urban design proposals in place can foster interest in public participation [9]. This offers new perspectives for designers and planners to "transforming planning work into an iterative, agile work process, in contrast to sequential and linear workflows that have shaped urban design practice in the past" [10]. Crivellaro et al. [11] have looked at how local people use data sharing through Facebook to mobilise around a local social movement. They recognised the importance of forming a like-minded community, but also acknowledged the struggle of the group to translate their emotions to the authority and decision makers. Hasler et al. [12] in another research found that the multiplication and diversity of contributions by citizens through digital participation increases complexity which means that prioritising relevant data can be problematic. This illustrates how data sharing can facilitate discussions that are planning-related, but turning them into actionable policies proven to be difficult. The research question this paper therefore seeks to explore is: *Can sharing emotional data offer a method for participation in the urban planning process*?

The paper presents a potential methodological contribution in terms of the incorporation of physiological sensing device and GPS tracking technologies for measure and analysing emotional data in urban environments. In order to do this, we first review the literature on the urban planning process, showing how the development of the discipline has sought to enable citizen participation. This is mapped against Arnstein's 'Ladder of Participation' to highlight how much of this participation typically does not enable citizens to control and act in the process, and is therefore the participation is often tokenistic. The potential of incorporating digital tools for participation is presented, and in particular the value of incorporating emotional data as a way of capturing a more person- centric understanding of urban space. In the study described in the paper, a small number of participants used a galvanic skin response (GSR) linked to location data to record stress levels in a walk through an urban city centre space with different characteristics. The findings aim to explore whether this emotional data might have benefit for enabling new models of shared data in urban planning processes.

1.1 The Challenge of Participation in the Urban Planning Process

"*Cities have the capability of providing something for everybody, only because, and only when, they are created by everybody*" [13]

Many people now live in cities, but despite Jacob's plea above, very few participate in how they are created, designed and planned. Therefore, the contribution of this study address the following broader question: 'how to enable meaningful participation in the urban planning process'? In order to do this, the paper first provides some context on how urban planning evolved and the developing role of participation. The origins if urban planning in the western world in the early 20th Century, were heavily influenced by the rational-comprehensive approach where the planning sequence involves: a survey of the region, an analysis of the survey, and finally the development of the plan [14]. Hall [15] argued that Geddes "gave planning a logical structure" by developing the survey-analysis-plan sequence of planning. However, this method of planning has been criticised to be too top-down; seeing the planner as "the omniscient ruler, who should create new settlement forms without interference or question" [15] as well as being too reductionist as planners have to make assumptions and predictions which required them to have complete certainty [16]. This then caused the planners to proceed on the basis of simplifying the world around them which later led to a lot of failure of the predictions [16]. The failures of the rational-comprehensive approach in urban planning led it to being succeeded by synoptic planning approach in 1960s and Hall argued that this change represents a fundamental shift in the role of the planners and their relationship with the public. However, Faludi [16] argued that this early form of participation was still based on the assumption that the society is homogenous – implying the homogeneity of interest. This means that participation is only required to validate and uncritically legitimise the goals of planning and any objection to planning proposal tends to be stigmatised [16].

Even when public participation has become an integral part of current urban planning process, Innes and Booher [6] argued that they still "do not achieve genuine participation". This is because current form of public participation does not satisfy members of the public that they are being heard and often does not improve the decisions that agencies and public officials make and [6]. The scepticism posed by Innes and Booher [6] to the way that current participation is being practiced could be traced back to Arnstein's widely known 'Ladder of Participation' [17]. As she put it, "there is a critical difference between going through the empty ritual of participation and having the real power needed to affect the outcomes of the process"[17]. The fundamental point of these criticisms was that if urban planners seek public participation, it is necessary that there be a redistribution of power [17]. She regarded power in public participation as a ladder or a spectrum ranging from 'nonparticipation' through to 'degrees of citizen power' (see Figure 2), which correspond to the degree of power or control participants can exercise in the quest of shaping the outcome. The ladder outlines steps of public participation from manipulation (level 1), education (level 3), and consultation (level 4), through to sharing power through 'partnership' (level 6) and beyond.

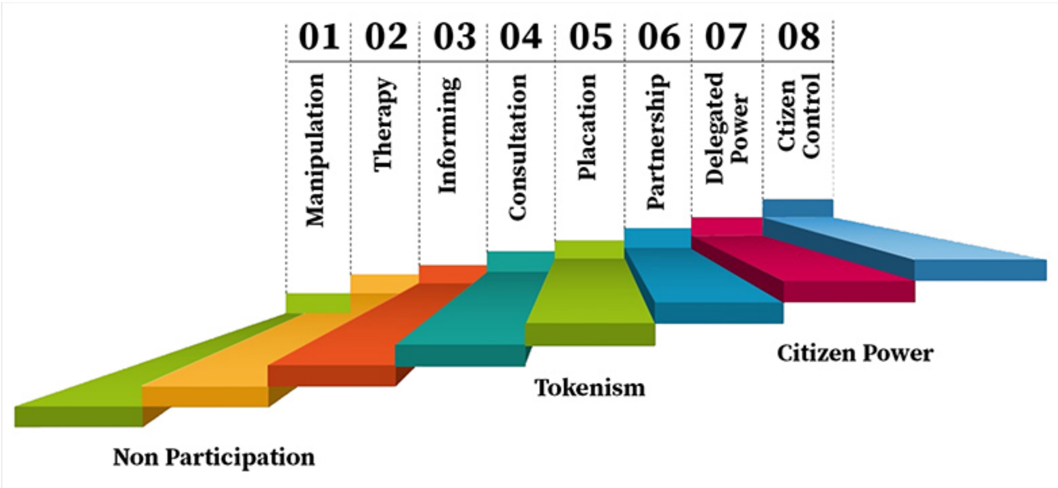


Figure 2. Arnstein's Ladder of Participation

Notably, Arnstein's framework regards consultation as 'tokenism' similar to the way Innes and Booher [6] viewed the level of public participation in current urban planning process. However, Painter [18] argued against Arnstein's analysis by stating that her ladder of participation model inaccurately apprehends power i.e. it confuses 'potential power' with 'actual power' [18]. While the official decision-making power may rest with institutional decision-makers in a consultation process, to regard the process as tokenistic disregards the fact that "if the exercise of influence [by participants] is effective, then this formal power is an empty shell"[18], p.23). He also argues that Arnstein's model often assume decision-making in planning occurs at a single point in the process. This ignores the fact that there is rarely an identifiable, or single, 'point of decision' in policy-making [18]. The primary value of this discussion is that it exposes that participation in planning can include the exercise of both formal and informal power. Hence, having power in decision-making processes is not the only way towards achieving genuine participation, as it could also be realised through ranges of other participatory activities - as long as the engagement with citizens contribute positively towards the outcome of a planning project.

1.1.1 Emotions and Planning

This paper explores whether sharing emotional data about a particular city setting can be used to inform the urban planning process. Although the link between the built environment and human's emotional aspects in urban planning research has found a growing interest in recent years, it is still a rather new approach in the field *[19]*. Typically in urban planning, planning is seen as an objective process, so emotion is not seen as qualities or analysis that can be meaningfully included in decision making *[20]*. They believe that urban planners should avoid allowing emotions to influence their analysis or recommendations and this is largely due to the fact that urban planners are taught to operate in a rational manner *[20]*. Despite the neglect of emotional aspects by many planning officials, there are also some urban planners who do recognise the importance of emotions within the field. For example, Lynch *[21]* recognises the emotional aspect through its link with emotions and mental maps while Ferreira *[22]* has urged that emotions should be presented as constructive drives with the power to positively inspire the planner to become a more competent professional. Porter et al. *[23]* on the other hand have claimed that attachments to community members improve the ability of planners to understand and work with residents while Gunder and Hillier *[24]* have interpreted planning issues through a Lacanian psychological model which acknowledge the entire process of becoming and being a planner is typically associated with strong emotional experiences. These authors have provided a meaningful theoretical discourse in terms of acknowledging the importance of emotions within urban planning. However, the majority of them have kept their focus on the planner side of the equation rather than on the users' side. Most of them recognise that planners should positively address emotions but very few have put the emphasis on citizens' emotional interactions with the urban environments itself. This should not be the case if we were to truly understand the relationship between emotions and urban spaces. According to Zeile et al. 'the long-term goal is to develop a new information layer for planners, in which a visualization of the measured spatial perception is possible. These visualizations allow conclusions about human behavior in an urban environment and enable a new citizen-centered perspective in planning processes' (Zeile, Resch, Exner, & Sagl, 2015). Hence, by linking it to public participations and the developments of digital tools, the next subsection will review some of the literature and studies around the spatial-emotional interactions of the city's users as its main focus to understand the significance of emotions in the urban planning field.

1.1.2 Digital Tools as Means for Measuring Emotions

Recent technological developments have allowed the incorporation of emotions in public participation within the planning field. It also allows current urban planners to increase their understanding of the relationship between citizens and urban spaces by measuring their emotions using newly developed digital tools. Most of the studies around this topic can largely be divided into three categories based on the tools they have used to extract emotional data either through: 1) social media, 2) mobile apps, or 3) physiological wearable devices. The similarities within all of these studies and perhaps the most important one for incorporating emotional experiences in spatial analysis is the capability to cross reference emotional data with accurate locational data i.e. the ability to geo-locate those data to a specific place within a city. For example, under the first category, Mislove et al. *[25]* extract the moods of people from different cities by mining information on social media, in this case, Twitter. This information however tends be at a low level of granularity; it is generally at a large spatial scale such as city, state or region and not collected at a detailed spatial level, such as a street or a city centre. Nevertheless, there is other recent research on mining emotional responses towards particular spaces from social media such as Tauscher and Neumann *[26]* who generated sentiment maps of tourist locations.

The Urban Emotion Research Lab developed a methodology for the extraction of contextual emotion information for decision support in spatial planning which enabled crowdsourcing physiological conditions (technical sensors measuring psycho-physiological parameters) and subjective emotions (human sensors contributing subjectively perceived emotions) [27-29] Drawing on this work, Hauthal and Burghardt [30] and Aiello et al., [31] both extract location-based emotions from photo titles, descriptions, and tags from Panoramio and Flickr respectively to generate maps of specific streets within various cities with emotional attributes. Mody et al. designed a location-based social networking tool that enables users to share and store their emotional feelings about places 'WiMo' *[32]*. They found that it was possible to create a recognisable and useable framework for gathering users individual emotional responses in a shared map interface. Key to this was defining 'places' rather than distinct geographical locations as these elicited an emotional response. Meanwhile, Zeile et al., *[33]* has established a dedicated algorithm to source emotional expressions from Twitter before plotting them onto the map of downtown Boston, USA.

Some researchers have started to focus on developing mobile apps, to gather users' wellbeing and feelings and to relate them to the geographic reference of their occurrence. For example, Ettema and Smajic (2015) utilised smartphones to gather self-recorded experiences of students during a walk. They have then later found out that the level of happiness was the highest in areas where many activities were happening and where a lot of people were around (Ettema and Smajic, 2015). MacKerron and Mourato (2013) in their project "Mappiness" used an iPhone app to collect frequent reports of temporary happiness at random times. They found that participants are generally happier in green or natural environments than in urban environments (MacKerron and Mourato, 2013). Similarly, Klettner et al., (2013) designed mobile apps called EmoMap to collect people's emotional responses to space through mobile phones, as well as modelling, and visualizing these data. The findings indicate that environments varying according to the amount of vegetation and traffic are perceived differently, with highest positive ratings for the urban-green area, and lowest ratings in the heavy traffic urban area (Klettner et al., 2013).

While semantic analysis from social media data and citizen feedbacks from mobile apps offer subjective evaluations on emotional experience of participants, physiological emotional extraction technique using wearable devices propose the investigation of the more objective element of emotions. This is on the basis that physiological responses would provide useful indications of the users' current emotional states when they interact with the physical environment. Over the last ten years, some urban researchers have been investigating this relationship and Nold's *[34]* 'emotional cartography' is perhaps the most significant in laying a fundamental underpinning to explore the changes in physiology in the urban space. His 'BioMapping' project, undertaken between the years 2004 to 2009, was the first to integrate GPS data with biometric human sensor data and explore the idea of visualising cartographically referenced emotional data. In the fieldwork, he gathered the change of the skin conductance levels and skin temperature of participants wearing a galvanic skin response (GSR) device as they walked in a number of cities, which was then mapped based on their GPS locations to describe areas in terms of emotional arousal *[34]*.

Similar work was done by Zeile et al. *[35]* who mapped the stress levels of cyclists in Cambridge, Massachusetts by measuring skin conductance levels during their ride using a GSR device. Apart from that, they have also attached a video recording device to allow footages to be taken along the route in order to accurately understand what caused the physiological changes in their participants *[35]*. A dedicated smartphone app was then used to allow geo-tagged reporting of the experiment. Their findings include the detection of what caused negative arousal in cyclists and they found out that the triggers include dangerous intersections, physical obstacles, pedestrians crossing, cars passing close by and damaged road surface *[35]*. They have also mapped the cycling route with all the moments of stress and triggers as well as some specific emotions based on the input from the participants and their rides.

The studies conducted by Nold *[34]* and Zeile et al. *[35]* all benefited from the use of the GSR device that offers physiological data collection of emotions of the participants. As the GSR device measures levels of emotional arousal through the change in skin conductance and resistance levels, these data can be easily quantified resulting in a more objective measure of emotions rather than just qualitative. This method is valuable since objective measurement of emotions has proven to be beneficial in terms of producing a more accurate representation of emotions. Hence, the next subsection will explore the mechanism operating the GSR device and its uses in measuring negative emotional arousal within the field. As mentioned previously, the work of Zeile and colleagues and Nold have undertaken key work *[34-36]* that has objectively investigated the relationship between emotions and physical environments using physiological responses methods. This work has laid important theoretical and methodological foundations for integrating the use of galvanic skin response (GSR) within urban spatial analysis and city planning, hence. In this paper we draw on these methodological approaches and further investigate the link between and urban spaces to gain understanding of how features in the urban space can be mapped against emotional response and the corresponding potential for this in participatory urban planning.

1.1.3 Physiological Measures of Stress Levels Using a GSR Device

A range of physiological measures have been employed to assess emotions in research. As mentioned before, physiological responses of the sympathetic nervous system, especially changes in electrodermal activity (EDA), blood pressure, heart rate, and cortisol levels, are broadly used to reflect changes in emotional arousals [37]. However, because the change in blood pressure and heart rate are also influenced by physical activities, the EDA offers a more accurate measure of emotional arousal[37]. Boucsein have discussed EDA at length and regarded it as a common term for all electrical phenomena including active and passive electrical properties which occurs in the skin [38]. One of the most well-known EDA measures is the galvanic skin response (GSR) defined simply as 'a change in the ability of the skin to conduct electricity' [38]. GSR can be measured using a GSR device in which the fundamental physiological mechanism that operates the response is 'the subtle change in sweat secretion from eccrine sweat glands throughout the body which increased when there is a high level of emotional arousal[36]. This phenomenon is called emotional sweating and can be observed and measured most easily and accurately on hands and feet. As the secretion of sweat increases, skin surfaces become moistier, thus improving the conduction of an electric current [36]. This allows for the skin conductance and resistance level to increase or decrease, and this change is recorded by the GSR device.

The current state-of-the-art in physiological sensor data analysis research suggests that negative emotional arousal can be correctly distinguished through the analysing of the skin conductance level. According to leading researchers in the field, such as Kreibig [39] and Rodrigues et al., [40], skin conductivity increases (while its resistivity decreases) when a negative experience occurs as this negative arousal is an indicator for a stress event. Zeile et al. supported this argument as their study has found out that "[if] for instance a test person has the experience of anger or fear – a negative emotion – skin conductance (the difference between sweat production and absorption of the skin) increases' [33]. Dakker et al. found in studies that GSR can be used not just to detect emotions but also for change detection in emotions since 'emotional experiences trigger changes in autonomic arousal quite impressively'. This can be used to link levels of emotional arousal with stress [41]. Bakker et al. distinguish stress in patterns of sharp rising emotional arousal at the peak, prior to a slow return to a relaxed state (see Figure 3) as highlighted in grey in the adapted GSR data graph below.

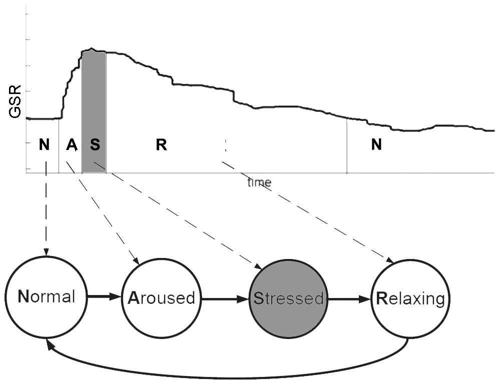


Figure 3. (adapted from Bakker et al.) – 'An example of acute stress pattern observed from GSR data and how it can be mapped to the symbolic (time-stamped) representation of person's stress' [41]

In this paper we focus on change detection in emotions using a GSR device and through correlating with changes in the urban context aim to investigate whether this has potential for mapping emotional change to particular urban planning features and qualities.

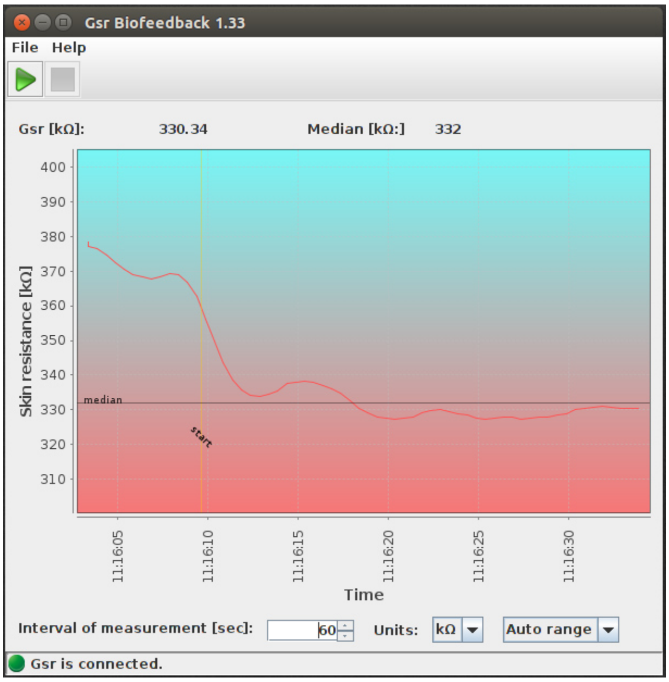
2. Materials and Methods

In this study, individual participants were asked to walk through a specific route in the city, whilst linked up to a galvanic skin response (GSR) device attached to their fingers and a GPS tracker app (Figure 4) in a backpack which they carried. Stress levels were measured using the GSR device which operates by detecting the subtle change in sweat secretion from eccrine sweat glands. Prior to the walk the quality of the GSR signal was checked in the visualisation software and the data feed was tested with the participant to resolve any potential issues and visualize the impact of breathing, movements, and talking.

Figure 4. Experiment set-up consisting of a finger mounted GSR device, a laptop, and a backpack linked to a GPS Phone Tracker App that was used to track participant's location at 1-minute intervals during the walk

During the fieldwork, the GSR device was first fixed to participants' fingers and then connected to a laptop that runs an accompanying software called GSR Studio (Figure 5) that records changes detected by the GSR device and automatically plots a readable graph of skin resistance levels against time. GPS data was recorded at 1-minute intervals during the walk, and the GSR data was then read in conjunction with features and characteristics of the urban setting to identify how this correlated to emotional arousal levels. In this study the focus is on positive and negative emotional arousal.

The GSR device used in this study[1] was a low cost and low-tech piece of equipment (costing under €100), and required no specialist training prior to use.



[1] https://www.happy-electronics.eu/biofeedback/products-en-2/skin-response-biofeedback/

Figure 5. GSR Studio software plots data into graph in real time. (photo from supplier)

2.2 Participants

A total of 9 participants, 3 males and 6 females, aged between 23-28 years old were recruited for the study. They were selected based on the criteria that they had lived in the city for between 1-3 years, so that they had some basic equivalence in terms of the background spatial knowledge of the setting. All of them were international students at the University of Plymouth. The participants were accompanied on the walk by a researcher, who followed the participant's' unobtrusively.

2.3 Setting

The route was chosen primarily because it covers three distinct areas in Plymouth City Centre. Participants were asked to walk from Plymouth Hoe, a popular recreational park in Plymouth, continuing their walk through Armada Way, a pedestrianized area, and ending at the North Road East (see Figure 6), a walk which took about twenty minutes in total. The urban spaces along the walk had different characteristics, ranging from the park at the beginning of the walk to a busy road at the end of the walk (see Table 1)

Figure 6. Study Route – Participants start walking from Plymouth Hoe, through Armada Way and ends in North Road East.

The route chosen for this study consists of three distinct areas summarized in the table below (Table 1):

Location on Walk	Name	Type of Space	Urban characteristics

Start of the walk	Plymouth Hoe	Park	Fully pedestrianised greenspace with the least traffic
Mid-way through the walk	Armada Way	Urban pedestrianised	A mix of both pedestrianised area and traffic (with some green space and natural features)
End of the walk	North Road East	Urban road	Busy road with very limited natural features

Table 1: Names and types of key urban spaces along the walking route- ranging from green space on Plymouth Hoe to a busy road at North Read East

The route included a number of junctions with varying levels of car and pedestrian traffic summarized in the table below (see Figure 7 and Table 2): These had different characteristics, with some junctions being busy with high levels of traffic, some being pedestrianized and some being road junctions but relatively quiet.

Figure 7. Participant's walking route – main crossings or junctions along the route

Name	Type of Space	Characteristics
Citadel Road	Busy road junction	Busy road with high levels of traffic
Royal Parade	Busy road, with busy pedestrian crossing	Busy road with high levels of traffic, including buses and taxis. Main pedestrian crossing of city centre with high pedestrian traffic
Mayflower Street	Road junction	Busy road
New George Street	Pedestrianised	Fully pedestrianised wide shopping avenue with high pedestrian traffic
Cornwall Street	Pedestrianised	Fully pedestrianised wide shopping avenue with high pedestrian traffic
Derry Avenue	Quiet road junction	Road with low levels of traffic

Table 2: Names and characteristics of road junctions along the walking route

There were also twelve identified crossings and junctions along the walking route which require participants to cross to get the other side. One of them is in the Plymouth Hoe area, six in the Armada Way area and five in the North Road East area. The nature of the setting means, with the different types of spaces can be said to correlate to typical regional city centre environments in the UK.

2.4 Limitations of the methods

There are a number of limitations in the methodology which should be taken into account, and these are described below in order to demonstrate how these were allowed for in the results. In terms of the participant's there was a low number, and we did not test participant's for their background spatial knowledge (although participants were selected based on spatial knowledge criteria). As a consequence, in our results the work is presented as exploratory in nature and the analysis is limited to qualitative outcomes. The second limitation of the study is the accuracy of the GSR equipment used in the study. A low cost GSR device was chosen for this study as it is aimed at demonstrating the possibility for the use of such equipment on a wider scale and by non-experts. Therefore the GSR results cannot be assumed to have the accuracy of data from products such as Movisens Edamove or Empatica E4 [38] (although Boucsein et al. do state that a finger GSR device, such as that used in this study can be more sensitive than a wrist-based device). According to Bakker et al. 'the reliable translation of physiological data gathered by using sensor technology into the "stress level rates" is only possible when additional sources of information are available' [41]. The results are presented comparatively showing the difference or similarities between participant's rather than as discrete, and were mapped using the GPS data against the features of the physical context. The use of GPS locational data mapped against the GSR data means that it was possible to assess the relation between spatial context and emotional response data at a fairly fine grain level.

3. Results

3.1. General Change in Participants' Emotions

The results showed that eight out of nine participants started with higher skin resistance level (less sweaty fingers) and ended the walk with a lower skin resistance level (sweatier fingers) (see Figure 8). As higher skin resistance level equates to lower stress levels, the change pattern in the results indicates that almost all the participants had lower levels of emotional arousal at the beginning of the walk i.e. at Plymouth Hoe park compared to when they were walking along the North Road East at the end of the experiment. Only one participant (participant 06) ended the walk at about the same level as when they started it.

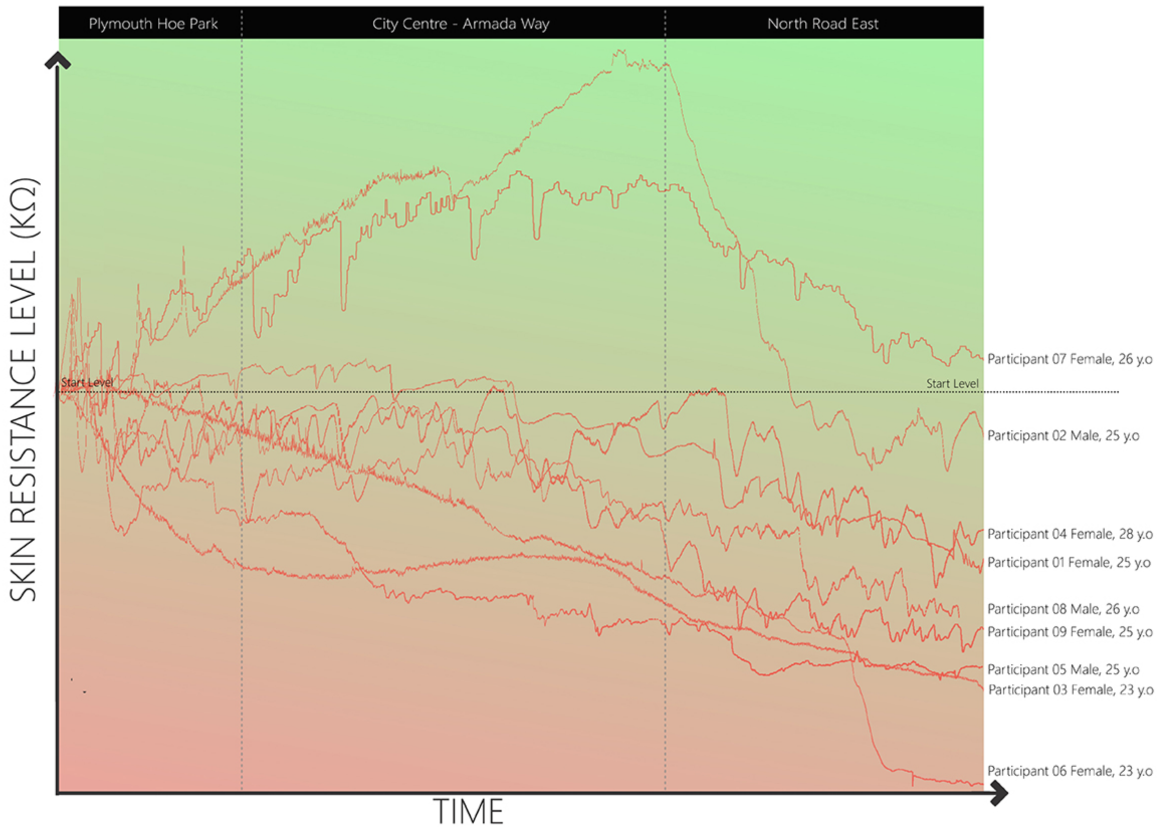


Figure 8. Results – Combined results of all participants showing a general trend of a higher skin resistance level at the start of the walk and lower skin resistance at the end.

It could also be observed that seven out of nine participant's recorded their highest level of skin resistance at the start of the walk in Plymouth Hoe than any other area of the walking route, and their skin resistance levels gradually decreased throughout the journey as they enter Armada Way and ended at the lowest level at the end of North Road East. If we see this pattern of emotional change as being linked to stress levels, then this result indicates that most participants find Plymouth Hoe park to be the least stressful area followed by Armada Way and then North Road East, where most participants find it to be most stressful. Two out of the nine participants (participant 02 and 06) on the other hand appeared to have their lowest stress levels when they were walking in the Armada Way. However, both of their apparent stress levels then changed dramatically as it steeply increased when they entered the North Road East area.

Further analysis on the participants' skin resistance levels can be made by drawing trend lines of their individual graphs for each area along the walking route. From the resul*ts i*t can be observed that the highest number of participants (5 out of 9 people) recorded an increasing level of skin resistance while walking through Plymouth Hoe. This suggests that most participants find Plymouth Hoe to be the least stressful place as their level of stress decreases as they walk through the park. Meanwhile, as participants walk through Armada Way, five participants experienced decreasing skin resistance compared to the number of people who experience increasing skin resistance levels (four participants). At North Road East, all of the nine participants recorded a decreasing skin resistance level. This further suggests that North Road East is the most stressful area compared to the other two areas as all of the participant's skin resistance levels decreased as they walked along the road.

The aggregate emotional arousal levels for all of the participants, where an average of the participants' data was visualised and projected onto the map of the city centre (see Figure 9), show a clear correlation between stress peaks and urban features.

Figure 9. Average of all the participant's stress levels combined and visualised onto the map of Plymouth City Centre, showing the 'peaks' of negative emotional response at road crossings and junctions.

The participant's data showed 'peaks' (that correspond to Bakker's et al.'s findings [41]) that can be identified as sharp increases in stress levels whenever they encountered road junctions along the walk. In addition, the figure also shows that as participants walk from Plymouth Hoe to North Road East, their apparent stress level gradually increases, providing another an indication as to how different areas within the city affect the level of stress of their inhabitants.

3.2. Change in Stress Levels at Crossings and Junctions

Another clear finding from this study is the relationship road crossings and junctions have with the change in stress levels of the participants. A typical participant is shown in Figure 10 with the crossings and GSR data levels indicated. The overall results (see Figure 11, 12 and 13) show that all of the crossings have at least three people experiencing a sudden drop in skin resistance level- or a stress 'peak'. Crossings at Citadel Road, Royal Parade, and Mayflower Street (see Figure 11) recorded the highest number of participants (i.e. all of the 6 participants) experiencing a sudden a stress 'peak'. Derry Avenue crossing and junctions at New George St. and Cornwall St., on the contrary, recorded the lowest number of participants (3 participants) that experienced the stress 'peak' (see Figure 12). The other 3 participants recorded generally unchanged stress levels when encountering these roads. Crossings at Citadel Road, Royal Parade and Mayflower St. are notably busier than junctions at New George St., Cornwall St., and Derry Ave. This resulted in more participants experiencing a sudden stress 'peak' at the former 3 crossings rather than at the latter 3. In fact, junctions at New George St. and Cornwall St. are at a fully pedestrianised area thus have no traffic presence.

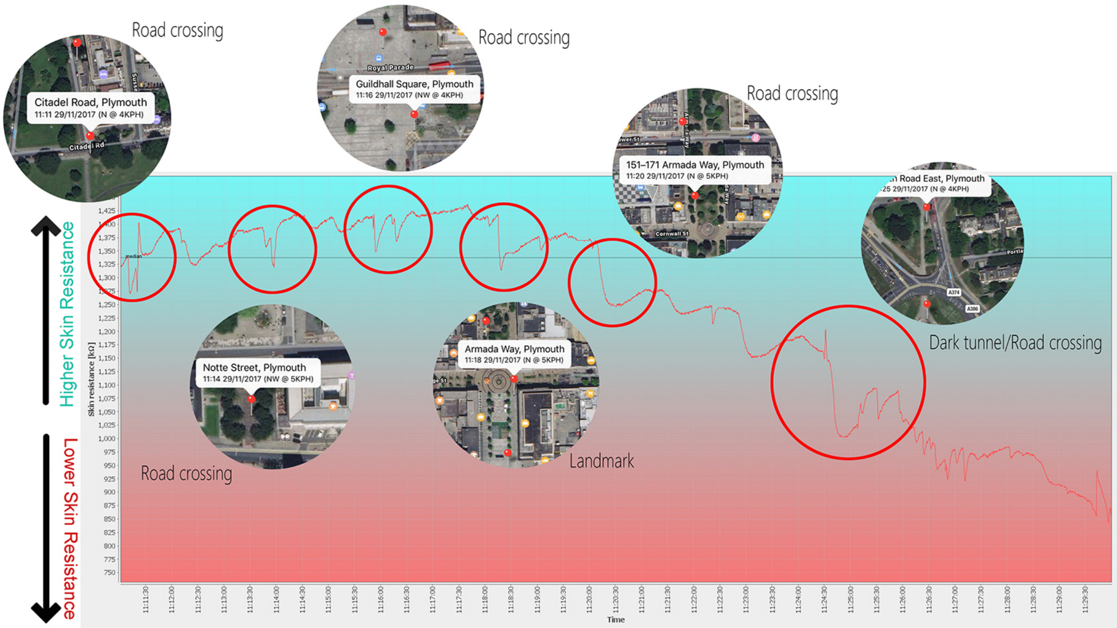


Figure 10. Typical participant's GSR data graph with crossings indicated and corresponding stress 'peaks' circled.

Figure 11. Crossings at Citadel Road, Royal Parade and Mayflower Street recorded the highest number of participants (all of the 6 participants) experiencing a stress 'peaks'.

Figure 12. Derry Ave. crossing and junctions at New George St. and Cornwall St. on the contrary, recorded the lowest number of participants (3 participants) that experience the stress 'peak'.

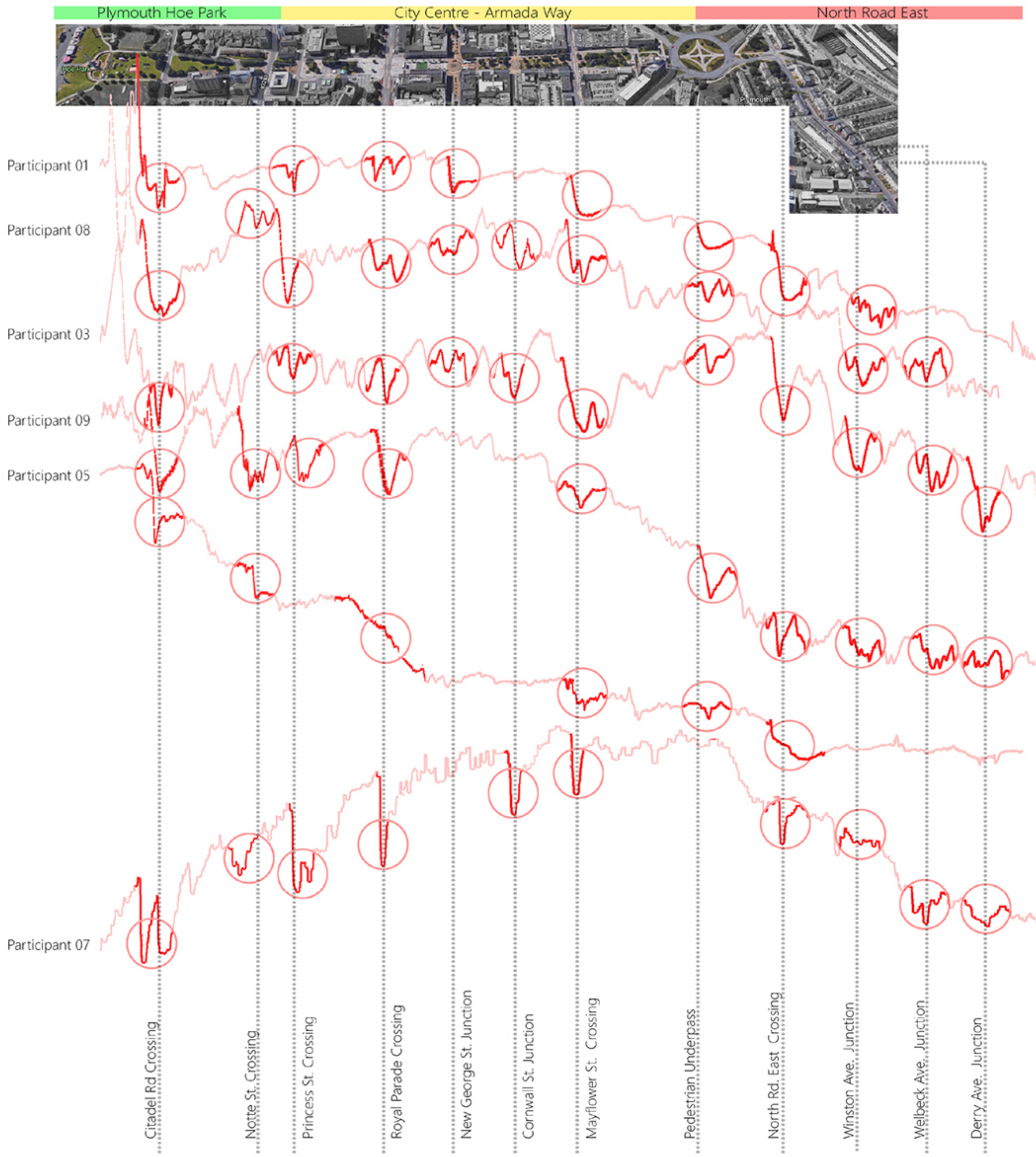


Figure 13. Overall results from all of the 6 participants with their graphs cross referenced with their GPS locational data. It could be noted that all of the crossings have at least 3 people experiencing a sudden drop in skin resistance level which equates to a stress 'peak'.

3.3. Relationship between Stress Levels and the Presence of Traffic and Natural Features

These different characteristics of each type of urban space encountered on the walk provides a clear variable which allows this paper to narrow down its research i.e. the relationship between emotions and physical environment can be studied in a more explicit manner. This means that the connection emotions have with specific urban features, in this case the presence of traffics and natural features, can be established more clearly. One observation that could be made from the findings is that area which was had the most 'green' space and natural features (Plymouth Hoe) created a generally less stressful environment for the participants. In contrast, areas with relatively less green space caused participants to feel less emotionally aroused. This observation is supported by many other previous studies such as MacKerron and Mourato's [42] "Mappiness" project and Klettner et al., [43] EmoMap project which have shown that green or natural environments have positive effects on emotions.

The results suggest that participants feel the least stressed at areas where the traffic levels were low and vice versa exhibited higher stress levels at busy roads. This can also explain the difference in number of participants experiencing stress 'peaks' at different junctions along the route. It was noted that Citadel Road, Royal Parade, and Mayflower Street junctions in particular have the most number of people experiencing the stress 'peaks' as they are significantly busier crossings than the others. Crossings at New George St., and Cornwall St. on the other hand have the least number of people experiencing sudden increase in stress levels because they are notably calmer and less busy in terms of traffic presence. In fact, junctions at New George St. and Cornwall St. are fully pedestrianised areas and thus the levels of traffic presence at these areas are actually zero. Previous studies, particularly, Klettner et al., [43] in their EmoMap project supported this claim as they have also found that participants give the lowest positive ratings (in terms of emotional response) when they are in an urban area with heavy traffic.

4. Discussion

As Nold and Zeile et al. have demonstrated [34, 35] emotional data can offer a new layer of data and provide new dimensions for both urban planners and citizens to share understanding of the city they live in. This study identified two potential ways in which emotional data can be used; firstly, through the link between a change in emotions and distinct urban planning features and secondly through the change in process to people gathering their own quantitative emotional data over time and in situ.

4.1. Changes in Emotions and the Link with Urban Planning Features

The findings show clear links between emotional response and corresponding characteristics of urban spaces as follows:

- Areas with more green space and natural features result in creating a less stressful environment for the participants (e.g. Plymouth Hoe).
- Areas with higher levels of urban traffic (more cars) result in creating a more stressful environment for the participants (e.g. North Road East).
- Road crossings and junctions result in stress 'peaks' or sudden increase in stress level by the participants (e.g. Royal Parade).

The study identified a correlation between emotional stress 'peaks' and urban design features and characteristics that could be used as a quantitative input into urban planning discussions. Whilst this study is small scale in terms of the number of participants, the nature of the findings does indicate that the method could be replicated with larger number of participants to increase the level of data and coverage. Shoval et al., **[36]** recognised that products of such analysis "lead to important insights into how people perceive and interact emotionally with the urban environment; it can therefore be of great use in an improved planning process" **[36]**. Zeile et al. have acknowledged that their results can be used "as a source of information to help improve bicycle traffic planning and to identify peaks in urban planning deficiencies" **[44]**. The current model of planning allows for consultation, but this is limited in terms of modes of participation and the information layer (see Figure 1 earlier in this paper). The gathering of emotional data and the subsequent understanding gained from this analysis would help create a readily available layer of shared data (Figure 14) directly inputting into the urban planning process.

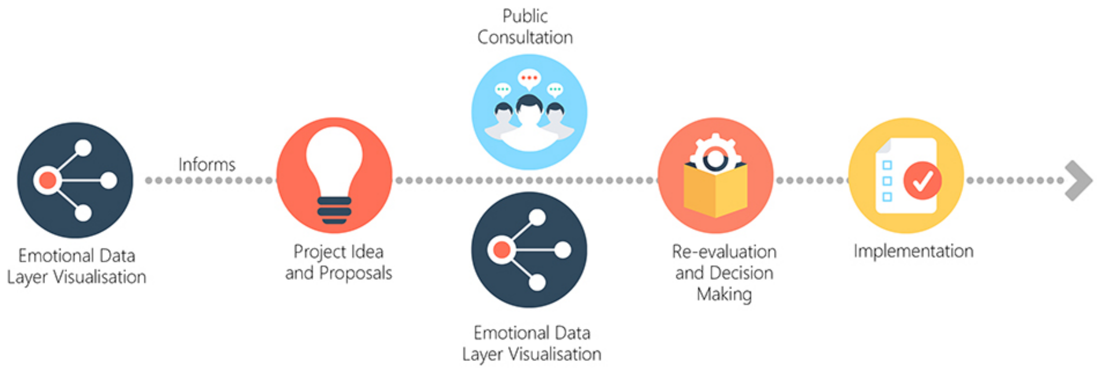


Figure 14. Emotional Data Model of participation in Urban Planning process

Whilst this study was undertaken in an existing city space, there is also the potential to draw some more general conclusions that could inform urban design proposals. It could therefore provide better insights of the city and its inhabitants - enabling a new citizen-centered perspective in urban planning processes.

4.2. Physiological Data for Citizen-Centric Participatory Planning

A shared approach to participation in urban planning processes could involve the provision of a new information layer within urban planning analysis through the gathering of citizens' emotional data through physiological responses methods. Unlike traditional forms of urban planning participation such as public meetings, consultations and hearings, this study suggests that humans, as the users of a city, could share qualitative emotional data. Jacobs **[13]** pointed out an important change in urban planning procedures which includes bottom up processes of participation that proactively involve citizens in urban change. This study has explored the potential of using physiological sensor technology to directly, objectively and cheaply measure citizens' emotions. Scaled up, this approach would mean that a city could involve citizens in sharing emotional data that would regularly provide new emotional data near real-time and as a readily available information layer to the city council. The model used in this study was for citizens to gather their own data and share it with others in order to understand their experience of the city in a more quantitative manner. However, it should be recognized that there are recognized and valid issues around the ethics and nature of consent around crowdsourcing urban data. For instance Gabrys argues that 'enabling citizens to monitor their activities convert these citizens into unwitting gatherers and providers of data' that can be used for political or commercial purposes beyond that which citizens are aware of [45]. But when used by the citizen for their own benefit Haklay asserts that 'the act of mapping itself can be an act of asserting presence, rights to be heard or expression of personal beliefs in the way that the world should evolve and operate' **[46]**

When reviewed against Arnstein's **[17]** 'Ladder of Participation', this method of using physiological device to gather citizens' emotional data would still fall under tokenism at either 'consultation' or 'placation' rung of the ladder. This is because participants of this study only provide emotional data input and do not have the actual power to influence how the data will be used in urban planning process. In the end, city planners still play a central role in planning decisions. However, the lack of 'citizen power' in this participatory method could be outweighed by the fact that using physiological sensing technology such as the GSR provides an accurate and objective data resource of citizens' emotions. It could also potentially be done at scale to create a large information database. During a traditional consultation process, citizens would subjectively express concerns about a planning project and the relevant authority would re-evaluate the project based on their feedback. In this citizen sensing participatory planning approach however, there is no need to wait until a planning project is established before actions or decisions could be made. In fact, the collection of emotional data can be continuous and ongoing and can be used at any time to inform any new planning projects. Therefore, for as long as the emotional data inputs from citizens influence the outcome of any planning decisions, even without any exercise of 'power', this form of participatory process could move beyond tokenism towards Arnstein's model of 'citizen power'.

5. Conclusions

A sharing cities approach can enable citizens to gather, share and analyse urban data which can give them an enhanced understanding and greater accessibility in city planning decisions [47]. This tends to relate to enabling citizens to gain access to self-generated sources of data, which enables a more informed understanding of issues in their urban environment. Digital participation using technologies such as physiological sensing devices, smartphones, and GPS technology present opportunities for a more effective and human-centred approach to participatory planning. This paper explored the potential of citizen's emotional data using digital tools such as the galvanic skin response (GSR) and GPS devices to objectively measure emotional response of people to a geo-located urban space. The study described in this paper extended the work of Nold (2009), Zeile et al. (2015) and Shoval et al., (2017) who found that emotional data mapped against high-resolution spatial analysis can have potential for informing urban planning decision making **[36]**. The potential of this method was discussed, and future directions for the research would be to replicate the study with larger numbers of participant's and to test a range of different urban settings. In particular, it would be valuable to test whether the findings around green space and busy roads creating different levels of emotional arousal could be replicated in different, but comparable cities. Further, the link between road junctions and stress 'peaks' could have potential to be tested with a range of urban planning features. In terms of participatory methods, these could be used by citizens at both pre- and post implementation stage to quantitatively measure the actual response of people to an urban planning project.

The results prove that there is a significant relationship between humans and the physical environments and by objectively measuring and analysing the data, this method provides innovative opportunities for urban planners to understand how citizens relate and interact emotionally to the city's urban environment. The data gathered through this approach could add a new dimension in the form of a new additional layer of information in urban planning analysis to assist urban planners in decision making processes. This has implications for urban planning policy in terms of how they could better incorporate participatory data into their practice, and how citizens could be empowered to share their emotional experiences of the city.

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Author Contributions:

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